CONFERENCE PROCEEDINGS

2005

California Plant and Soil Conference

Science & Policy in California Agriculture

California Chapter of the American Society of Agronomy

Co-sponsored by the California Plant Health Association

February 1 & 2, 2005

Modesto DoubleTree Hotel
1150 9th Street, Modesto, California

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CALIFORNIA PLANT & SOIL CONFERENCE
TUESDAY, FEBRUARY 1, 2005

SCIENCE & POLICY IN CALIFORNIA AGRICULTURE

10:00 **General Session Introduction** – Session Chair & Chapter President –**Ron Brase**, California Ag Quest Consulting

10:10 **Cars or Cows: Science & Policy Issues in Air Quality** – Mathew Summers, Office of Agriculture & Environmental Stewardship, CDFA

10:40 **Science & Policy Issues in Crop Biotechnology** – Kent Bradford, Director, Seed Biotechnology Center, UC Davis

11:10 **Science & Policy Issues in Water Resources Management** – Timothy Quinn, Metropolitan Water District of Southern California

11:40 Discussion

12:00 **Western Plant Health Association Luncheon Speaker: Carol Whiteside, Great Valley Center**

CONCURRENT SESSIONS (PM)

I. IRRIGATED LAND WAIVERS

1:30 Introduction - Session Chairs: **Allan Fulton,** UCCE, Tehama County and **Mary Bianchi**, UCCE**,** San Luis Obispo County

1:40 **Water Quality and Agriculture- The big Picture** – Gary Carlton, Board Member, California State Water Resources Control Board

2:00 **A New Culture For Implementing Agriculture Regulatory Programs** – David Guy, Sacramento Valley Water Quality Coalition

2:20 **The Role For Water Quality Monitoring at a Watershed Level** – Mike Johnson, John Muir Institute, UC Davis

2:40 Discussion **3:00 BREAK**

3:20 **Water Quality Monitoring at the Farm Level**, Ken Tate – Agronomy & Range Science Department, UC Davis

3:40 **What's the Bottom Line? Estimating Costs and Benefits for Central Coast Farm Water Quality Conservation Practices** – Laura Tourte, UCCE, Santa Cruz County

4:00 **Decision-Making Tools for Pest Management – Additions to the Pest Management Guidelines** – Joyce Strand, UC IPM, UC Davis

4:20 Discussion

4:30 **ADJOURN**

II. TECHNOLOGY TO ADDRESS AIR QUALITY

1:30 Introduction – Session Chairs: **Charles Krauter**, CSU Fresno; **Bob Fry**, NRCS

1:40 **Current Issues and Policies Related to Air Quality and Agriculture** – Rick McVaigh, San Joaquin Valley Air Pollution Control District

2:00 **Current Air Quality Issues From the Ag Industry's Perspective** – Roger Isom, California Cotton Ginners Association

2:20 **Air Quality Issues and Regulatory Policy in Animal Agriculture** – Frank Mitloenher, UCCE, Animal Science Dept., UC Davis

2:40 Discussion **3:00 BREAK**

3:20 **Particulate Matter: Are the Ag Figures True?** – Barry Goodrich, Center for Irrigation Technology, CSU Fresno

3:40 **Mitigating Dust Emissions in the San Joaquin Valley by Reduced Tillage** – Jeff Mitchell, UCCE, Dept. of Vegetable Crops, UC Davis

4:00 **New Methods of Measuring Atmospheric Ammonia Emissions From Agricultural Practices** – Dave Goorahoo, CIT, CSU Fresno

4:20 Discussion

4:30 **ADJOURN**

ADJOURN to a Wine and Cheese Reception *in the Poster Room.*

A complimentary drink coupon is included in your registration packet.

WEDNESDAY, FEBRUARY 2, 2005
CONCURRENT SESSIONS (AM)

III. PEST MANAGEMENT

8:30 **Introduction** – Session Chairs: **Tom Babb**, CA Dept. of Pesticide Reg.; **Jeff Wong**, Cal Poly SLO

8:40 **GMOs in Agriculture, How They Fit in a Pest Mgmt. System** – Rick Roush, UC IPM, UC Davis

9:00 **Consumer Response to BT Sweet Corn in a Politically Charged Environment** – Craig Macmillan, Dept. Hort.& Crop Sci., Cal Poly, SLO

9:20 **New Weed Issues in Vineyards (Marestail and Fleabane)** – Kurt Hembree, UCCE, Fresno County

9:40 Discussion **10:00 BREAK**

10:20 **New Alternatives to Herbicides in Cropping Systems** – Steve Fennimore, UCCE, Monterey Co.

10:40 **Alternative Herbicides in Urban Landscapes** – Cheryl Wilen, UCCE, San Diego County

11:00 **Environmentally Responsible Almond Pest Mgt.** – Roger Duncan, UCCE, Stanislaus Co.

11:20 Discussion

IV. NUTRIENT MANAGEMENT

8:30 **Introduction** – Session Chairs: **Tim Hartz**, UC Davis; **Joe Fabry**, Fabry Ag Consulting

8:40 **Phosphate and Potassium Management in Alfalfa** – Rob Mikkelsen, Potash & Phosphate Institute

9:00 **Perchlorates in Vegetables** – Husein Ajwa, UCCE, Dept. of Vegetable Crops, UC Davis

9:20 **Dormant-Season Sampling of Peach Trees** – Scott Johnson, Dept. of Pomology, UC Davis

9:40 Discussion **10:00 BREAK**

10:20 **PAM Effects on Soil Nutrient Dynamics** – Mike Cahn, UCCE, Monterey County

10:40 **Nutritional Control of Early Senescence in Pima Cotton** – Bob Hutmacher, UCCE, Agron. & Range Science, UC Davis

11:00 **Tissue Testing in Grapes – Leaf or Petiole?** – Danyal Kasapligil, Dellavalle Laboratory Inc.

11:20 Discussion

12:00 **ANNUAL CHAPTER BUSINESS MEETING LUNCHEON**.
Presentation of Honorees, scholarship awards and election of new officers

CONCURRENT SESSIONS (PM)

V. IRRIGATION & WATER MANAGEMENT

1:30 **Introduction** – Session Chairs: **Joe Fabry,** Fabry Ag Consulting; **Jim Ayers**, USDA

1:40 **Current Understanding of Regulated Deficit Irrigations in Walnuts** – Allan Fulton, UCCE, Tehama County

2:00 **Improving Nutrient Application Uniformity of Water Run Fertilizers** – Larry Schwankl, UCCE, Dept. of Land, Air and Water Resources, UC Davis

2:20 **Effect of Fertigation Strategy on Nitrate Leaching for Different Micro-irrig. Systems and Soil Types –** Blaine Hanson, UCCE, Dept. of Land, Air and Water Resources, UC Davis

2:40 **Subsurface Drip Irrigation Improves Potential Profits for Growing Peaches** – Dave Bryla, USDA

3:00 Discussion

3:20 ADJOURN

VI.

VI. MANAGING SOIL ORGANIC MATTER

1:30 **Introduction** – Session Chairs: **Will Horwath,** LAWR, UCD; **Bruce Roberts**, CSU Fresno

1:40 **Managing Soil Organic Matter** – Will Horwath, Dept. of Land, Air and Water Resources, UC Davis

2:00 **Rice Management Impacts on Soil Organic Matter** – Chris van Kessel, Agronomy & Range Science, UC Davis

2:20 **Orchard Management Impacts on Soil Organic Matter** – Brent Holtz, UCCE, Madera County

2:40 **Cotton Management Impacts on Soil Organic Matter** – Bruce Roberts, Dept. of Plant Science, CSU Fresno

3:00 Discussion

3:20 ADJOURN

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California Chapter of American Society of Agronomy

Past Presidents

Year	President
1972	Duanne S. Mikkelson
1973	Iver Johnson
1974	Parker E. Pratt
1975	Malcolm H. McVickar
1975	Oscar E. 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	G. 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
1998	Shannon Mueller
1999	D. William Rains
2000	Robert Dixon
2001	Steve Kaffka
2002	Dave Zoldoske
2003	Casey Walsh Cady
2004	Ronald Brase

California Chapter of American Society of Agronomy

Past Honorees

Year	Honoree	Year	Honoree
1973	J. Earl Coke	1998	Bill Isom
1974	W.B. Camp		George Johannessen
1975	Milton D. Miller		Ichiro "Ike" Kawaguchi
1976	Malcom H. McVickar	1999	Bill Fisher
	Perry R. Stout		Bob Ball
1977	Henry A. Jones		Owen Rice
1978	Warren E. Schoonover	2000	Don Grimes
1979	R. Earl Storie		Claude Phene
1980	Bertil A. Krantz		A.E. "Al" Ludwick
1981	R. L. "Lucky" Luckhardt	2001	Cal Qualset
1982	R. Merton Love		James R. Rhoades
1983	Paul F. Knowles		Carl Spiva
	Iver Johnson	2002	Emmanuel Esptein
1984	Hans Jenny		Vince Petrucci
	George R. Hawkes		Ken Tanji
1985	Albert Ulrich	2003	Vashek Cervinka
1986	Robert M. Hagan		Richard Rominger
1987	Oscar A. Lorenz		W. A. Williams
1988	Duane S. Mikkelsen	2004	Harry Agamalian
1989	Donald Smith		Jim Brownell
	F. Jack Hills		Fred Starrh
1990	Parker F. Pratt	**2005**	**Wayne Biehler**
1991	Francis E. Broadbent		**Mike Reisenauer**
	Robert D. Whiting		**Charles Schaller**
	Eduardo Apodaca		
1992	Robert S. Ayers		
	Richard M. Thorup		
1993	Howard L. Carnahan		
	Tom W. Embelton		
	John L. Merriam		
1994	George V. Ferry		
	John H. Turner		
	James T. Thorup		
1995	Leslie K. Stromberg		
	Jack Stone		
1996	Henry Voss		
	Audy Bell		
1997	Jolly Batcheller		
	Hubert B. Cooper, Jr.		
	Joseph Smith		

California Chapter
American Society of Agronomy

2004 Chapter Board Members

Executive Committee

President	Ronald Brase, California AgQuest Consulting, Inc.
First Vice President	Bruce Roberts, Plant Science Dept. CSU Fresno
Second Vice President	William Horwath, Dept. of Land, Air & Water Resources, UC Davis
Secretary-Treasurer	Ben Nydam, Dellavalle Laboratory, Inc.
Past President	Casey Walsh Cady, California Dept of Food and Agriculture

Governing Board Members

One-year term	Tom Babb, CA Dept. Pesticide Regulations
	Bob Fry, USDA-NRCS
	Charles Krauter, Plant Science Dept. CSU Fresno
Two-year term	James Ayars, USDA-ARS
	Joe Fabry, Fabry Ag Consulting
	Tim Hartz, UCCE, UC Davis
Three-year term	
	Mary Bianchi, UCCE San Luis Obispo County
	Allan Fulton, UCCE Tehama County
	Jeffrey Wong, Hort and Crop Science, Cal Poly, SLO
Advisor	Dennis Westcot, Central Valley Regional Water Quality Control Board

2005 Honorees

Wayne Biehler

Charles Schaller

H. Michael Reisenauer

Wayne E. Biehler

Professor of Agronomy Emeritus, Fresno State

A native son of Kansas, Wayne was raised on a dryland wheat farm. Wayne completed a bachelor's degree in Botany at Fort Hays State University before enlisting in the U.S. Navy in 1943. After active duty in World War II, he continued his education at UC Davis where he completed a master's degree in Agronomy in 1951. He started his teaching career at Fresno State College that same year.

Wayne served our country as a Navy Officer in World War II. During his three years of active duty in the Pacific Theater, he participated in major combat missions. As a member of the famed amphibious Ship LSM 202, Wayne was in the first wave of assault landings at Imo Jima. He was involved in other combat efforts leading to the liberation of the Pacific Islands. Wayne continued his military service as a member of the Navy Research Unit based at Fresno State. After 23 years in the Research Reserve Unit, Wayne retired as a Lieutenant Commander.

Wayne began teaching at Fresno State in 1951 and spent the next 38 years teaching basic agronomy courses. Wayne served as chair of the Plant Science Department for 18 years. In this capacity, he was involved with the recruitment and counseling of students. Wayne dedicated his career to the education and training of young agronomists. His primary career objective was to prepare graduates of Fresno State for active roles in agriculture. He was instrumental in training a generation of agronomists who are currently involved in every aspect of California's diverse industry. Students and their placement into agriculture careers became a primary concern of his during his teaching years. A phone call or a verbal recommendation from Wayne Biehler would open many doors to Fresno State graduates. Due to his dedicated nature many of his former students have leadership roles in California's agriculture. As the department chair, he also provided leadership in the hiring and development of the department's faculty. Much of the department's success over the past 30 years is due to his stewardship.

Wayne was also a major force behind the development and utilization of the University Farm Laboratory. This facility provides a working laboratory for student enterprise projects and applied field research for faculty and students. Many Fresno State graduates received their first introduction to production farming from projects conducted on the University Farm. He was involved with the introduction of winter forage cereal mixes that are commonly grown today for hay and silage. He was instrumental in helping create the vision of a center for irrigation technology at CSU Fresno.

Wayne was involved in the early organization of what has become Ag One, the alumni organization coordinating scholarships and grants for agriculture students. This organization grew out of his original "Agronomy Club" of alumni supporters and friends. Wayne received the Salgo Noren Award for Excellence in Teaching in 1981. This honor is the highest award bestowed by the College of Agriculture Science and Technology.

This award from the California Chapter of the American Society of Agronomy is to acknowledge Wayne Biehler's dedication to teaching and his contributions to California's agriculture.

Charles Schaller

Professor, Emeritus, UC Davis

Dr. Charles Schaller retired from the University of California, Davis, in 1985, after a 39-year career as a geneticist and plant breeder. He is recognized as one of the world's authorities on the genetics and breeding of barley, especially in the area of disease resistance. Information and materials developed in his program have been utilized extensively in breeding programs throughout the world.

Dr. Schaller received a B.S (Soils) in 1941, M.S. (Agronomy) in 1943, and a PhD (Agronomy and Plant Pathology) in 1946, all from the University of Wisconsin. He began his career at UC Davis in August 1946, and was involved with breeding wheat (from 1946 to 1961) and cotton (beginning in 1966), as well as barley. His improved barley varieties combined disease resistance with better straw strength and have proven to be valuable germplasm sources of disease resistance and adaptation genes for many countries, especially those in areas with a Mediterranean-type climate. He emphasized powdery mildew, net blotch, scald, and BYD, screening the world collection of barley for resistance to these diseases and identifying several major genes conditioning resistance that became widely used in breeding programs throughout the world. Especially noteworthy is his research leading to the discovery of the Yd2 gene for resistance to the barley yellow dwarf (BYD) virus. The disease was first identified in California in 1951 and subsequently recognized as a major disease throughout the world on barley, wheat, and oat. His research led to the release of 12 barley varieties and four wheat varieties; additional barley varieties were released subsequent to his retirement based on germplasm that he developed. The increased productivity of Dr. Schaller's varieties was conservatively estimated to provide $30,000,000 annually in direct benefits to California's economy, with little of no increase in production costs. At the time of his retirement, 75-80% of the annual California barley crop was grown with UC varieties that he developed.

Dr. Schaller served as major professor for some 25 graduate students, including several who became outstanding barley researchers. He also advised numerous undergraduate students and taught the Cereal Crops of the World course at UC Davis for over 30 years. He wrote 54 journal articles, 7 abstracts, 45 limited edition reports, and chapters for 4 books. He received a Certificate of Appreciation from the California Department of Food and Agriculture in 1979 for his work on the development of cotton varieties with verticillium resistance, a breeding line evaluation program, and service to the One-Variety Cotton District on behalf of the San Joaquin District Continuous Cotton Testing Committee. He was named Fellow of the American Society of Agronomy (1983) and of the Crop Science Society of America (1985) in recognition of his career accomplishments. He is a member of Alpha Zeta, Phi Sigma and Sigma Xi honorary societies and of the American Society of Agronomy and the American Phytopathological Society professional societies.

H. Michael Reisenauer

Professor Emeritus of Dept. Land, Air and Water Resources, University of California, Davis

Dr. Reisenauer was born in Portland, Oregon. He attended the University of Idaho, Moscow where he attained a Bachelor of Science Degree in Agronomy with an emphasis in Soil Science. He continued his education at North Carolina State College in Raleigh where he earned a Doctor of Philosophy Degree in Soil Science and minors in Botany and Chemistry in 1949. While attending North Carolina College, Dr. Reisenauer proudly served his country in the United States Navy from 1942 to 1946. Following his Ph.D., Dr. Reisenauer briefly served as a Lecturer in Agronomy before becoming an Assistant Professor of Soils and Associate Professor of Soil Science in the Agricultural Experiment Station at Washington State University, Pullman, Washington in 1949. While at Pullman, he taught graduate courses in Soil Fertility and Chemistry and setup and operated the State Soil Testing Laboratory. He was responsible for developing soil test correlations for the state while supervising the establishment of three out-lying soil nitrate and moisture testing laboratories. In Pullman, he conducted research on nitrogen, sulfur, phosphorus and molybdenum fertilizer requirements of cereals, alfalfa and peas.

Dr. Reisenauer, attained the rank of Full Professor in 1959 at Pullman. In 1962, he joined the Kearney Foundation of Soil Science as a Lecturer and Soil Scientist. While in the Kearny Foundation, he was instrumental in determining the role of trace elements in plant nutrition. He discovered the relationship of cobalt to nitrogen fixation, which he documented in a paper in Nature. He published a notably paper in 1963 on the determination of leghemoglobin in legume nodules. Dr. Reisenauer joined the Department of Soils and Plant Nutrition in 1970. He was elected “Fellow of the American Society of Agronomy” in the same year.

Dr. Reisenauer’s career is exemplified through his major contributions to plant nutrition and soil fertility. Later in his career he concentrated on mechanisms of nitrogen assimilation by plants, behavior of metals in soils and their uptake by plants and the development of analytical methods for characterizing soil as a plant growth medium. His research provided new insights into the role of plant root cell metabolites. He was one of the early pioneers in the use of solution cultures to understand plant nutrition requirements. He was also instrumental in showing the role of root exudates in the solubilization of soil manganese. This important discovery contributed to the understanding of how plants influenced their environment to aid in the acquisition of essential nutrients. Dr. Reisenauer wrote numerous articles, chapters and reports on plant nutrition and soil fertility. He contributed significantly to the Western Fertilizer Handbook.

His career long work on nitrogen fixation, role of soil metals in plant nutrition and general plant-soil relationships gained him the highest international recognition. He gave numerous invited talks and served in the capacity of editor for numerous books and reports.
He served on numerous University committees and maintained a solid record of public service.

This award from the California Chapter of the American Society of Agronomy is to acknowledge Dr. Reisenauer’s dedication to teaching and research and for his numerous contributions to California’s agriculture.

2005 Scholarship Recipent and Essay

Essay question:

What, if any, should the role of science be in agricultural policy formation in California? Provide an example to illustrate.

Scholarship Committee:
Casey Walsh Cady
Allan Fulton
Mary Bianchi
Jeff Wong

2005 Winning Scholarship Essay

Jodi Winemiller
Environmental Studies – Agroecology Major, UC Santa Cruz

Agricultural science has played a fundamental role in the shaping of current agricultural policy and is a powerful tool that must be utilized wisely to provide both accurate and appropriately directed research. In structuring agricultural research in a way that both integrates current scientific perspectives with local knowledge, and also focuses on questions that address social, economic and environmental issues, we may be able to better inform policy makers, thereby enhancing the influence of research on policy formation.

The role of agricultural science in policy formation should therefore be to provide relevant information with practical management implications. By framing research in a way that is firmly rooted in specific place or situation, we can more adequately address interconnected social, environmental, and economic aspects of agriculture. Additionally, by working directly with farmers, we can utilize their wealth of knowledge, using it as a foundation upon which to construct research that incorporates their needs and ideas. In integrating principles such as these, agricultural science would be able to shift its political voice to one that is a more interdisciplinary reflection of current needs and long-term goals, making it a sharper more defined tool in policy formation.

As an example, for my senior thesis, I am estimating biological nitrogen fixation of legume cover crops in order to better understand nutrient cycling within organic systems along the central coast of California. This is part of a larger project, which is working with local organic farmers to identify the potential for nutrient leaching within these systems, in order to formulate more realistic expectations of nutrient losses from farms, and better understand ways in which to decrease that loss. This research was designed with the goal of collecting data that is highly relevant to current environmental and political issues, generating information that may be crucial to influencing the EPA’s policy direction concerning nutrient loading into waterways. Agricultural research has an inherently critical role to play in California policy formation, and must therefore work to create interdisciplinary research goals that address issues of significance to both farmers and policy makers.

Session I

Irrigated Land Waivers

Session Chairs:

Allan Fulton, UCCE Tehama County

Mary Bianchi, UCCE San Luis Obispo County

Water Quality and Agriculture: The Big Picture

Gary Carlton, Board Member
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Abstract
The California State Water Resources Control Board (SWRCB) is the principal water quality regulatory authority in the state. The SWRCB works with the nine Regional Water Quality Control Boards (RWQCBs) to regulate discharges that may affect the quality of the waters of the state using a variety of regulatory tools for compliance and enforcement. Numerous changes in law and regulation have changed the way the SWRCB and RWQCBs regulate water quality. These changes and other factors require innovative approaches and creative solutions to effectively regulate water quality. Cooperation and participation by the regulated community is also essential for a successful program.

Introduction
California has long been a leader in water quality protection. The regulatory authorities and responsibilities of the SWRCB are spelled out in the Porter-Cologne Water Quality Control Act of 1969. Porter-Cologne predates the federal Clean Water Act which, in some respects, is modeled after Porter-Cologne. As Porter-Cologne has evolved through various additions and amendments, so have some of the approaches to regulation. This is particularly true for irrigated agriculture.

This paper looks at some of the evolutionary changes in law and regulation and describes how the SWRCB and nine RWQCBs (collectively, "Boards") are responding to them.[1]

Regulatory Considerations
The regulatory process is guided by the following four factors or considerations:

1. Regulation must be balanced

The California legislature made a number of legislative findings when it passed the Porter-Cologne Water Quality Control Act in 1969. They are found in Section 13000 of the Water Code:

> "…the people of the state have a primary interest in the conservation, control, and **utilization of the water resources of the state**, and that the **quality of all the waters of the state shall be protected** for use and enjoyment by the people of the state."
>
> "…activities and factors which may affect the quality of the waters of the state shall be regulated to attain the **highest water quality which is reasonable, considering all demands being made** and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible."

The first factor is the need to balance the utilization of the resource with the protection of the resource and the environment. By law, the SWRCB cannot permit the over-utilization or degradation of the resource as has occurred in some countries. In the same manner, the SWRCB can't over-protect the resource to the point of loss of some beneficial uses.

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[1] Further information on the regulatory programs described in this paper and contact information for SWRCB and RWQCB program managers can be obtained on the SWRCB's web site at www.waterboards.ca.gov.

The legislature clearly intended that a balance be struck between protection and utilization. This statutory requirement introduces a degree of subjectivity and discretion into the regulatory process, and forms the battleground over which regulatory issues are fought before the Boards. Water quality regulation would be much easier if the Boards could regulate at either extreme.

2. Regulation must involve all stakeholders and interested parties

The second factor is the fact that very little can be accomplished administratively or in isolation of other factors or interests. Ninety four years ago John Muir said that when we try to pick out anything by itself, we find it hitched to everything else in the universe. If that was true in the last century, it is even more so today, especially with issues related to environmental protection. The large capital improvement projects that were built in the last 50 years, particularly the big water development infrastructure projects demand a much higher level of environmental review and far greater stakeholder involvement than in the past. O'Shaughnessy Dam in the Hetch-Hetchy Valley was built with very little consideration given to environmental protection. John Muir tried unsuccessfully to prevent the construction of this facility almost one hundred years ago. Such a structure would never be contemplated today, and there is growing interest in removing the dam and restoring the Valley.

3. Regulation must meet complex legal requirements and be responsive to legislative and judicial mandates

The third consideration is the complex framework of State and Federal law that the SWRCB and RWQCBs operate under, and the legislative and judicial mandates that they must respond to. The regulatory process is not always in a straight line but is guided by the requirements of new laws and regulations, court orders and political realities.

A recent example is the Headwaters - Talent decision in Oregon in which the 9th Circuit Court of Appeals ruled that NPDES permits are required for applications of aquatic pesticides to surface waters. Because of this ruling the SWRCB went through a crash process in 2001 to adopt a statewide general permit for applications of aquatic pesticides. This action brought hundreds of dischargers under the highest level of regulation, regardless of whether or not they were a threat to water quality (SWRCB, 2001). The general permit was replaced in 2004 by separate water quality orders for aquatic weed control and vector control (SWRCB, 2004b).

Another recent example is the changes made to Water Code Sections 13269 and 13350 by Senate Bill 390 in 1999 relating to the expiration of and requirements for renewal of waivers of Waste Discharge Requirements. This important issue is discussed below in more detail.

4. Regulation is directed by available resources

The fourth factor directing the SWRCB's ability to regulate is the availability of resources. There are hundreds of thousands of discharges throughout the state, and a comprehensive regulatory program to address them would require a commitment of resources far in excess of what can be supported with the current budget or reasonably contemplated under the most optimistic of revenue forecasts. As a result, some regulatory options are not feasible, and a measure of creativity is needed to implement mandated programs.

In the past, many SWRCB and RWQCB regulatory activities were supported by the State general fund and other sources such as federal funds and penalty assessments. The ongoing budget crisis in

California has accelerated a trend towards total fee support for regulatory programs. The SWRCB recently adopted a fee schedule for all discharge permits and is developing a fee-supported workplan for agricultural waivers. The SWRCB and RWQCBs are not yet able to implement fully developed waiver programs, but do anticipate significant improvements in regulatory effectiveness.

These considerations can be summarized in a single statement:

> The challenge is to meet our statutory obligations in a way that balances the utilization and protection of natural resources with available human and financial resources in consideration of the diverse interests of all parties.

Historic Approach

Under the old Nonpoint Source Management Plan (SWRCB, 1988), the preferred approach for regulating agricultural and other nonpoint source discharges was through a progressive series of management options consisting of various combinations of 'carrot and stick' that were widely known as the three-tiered approach. Those tiers are:

Tier one - Nonregulatory or self-determined implementation of Best Management Practices (BMPs)

Tier two - Regulatory incentives and encouragement of BMP implementation

Tier three - Permits and enforcement to require implementation of BMPs

While there was no legal requirement to implement one tier before another, it was preferred to regulate at the least intrusive level that is effective in protecting water quality, i.e., Tier 1. The ability to regulate in this manner has been severely limited by the changes to Water Code Sections 13269 pertaining to waivers. Changes at the federal level to the Clean Water Act and federal court rulings (e.g. the Talent decision) are also bringing more discharges under formal permitting requirements (i.e., Tier III regulation).[2]

It is important to note that Tier 1 is not the optional or discretionary implementation of BMPs but is "self-determined" implementation of BMPs. Compliance with water quality rules and regulations is not optional, but the discharger can determine how to comply with the regulations by selecting the most appropriate BMPs.

The three-tiered approach has been replaced by the NPS Implementation and Enforcement Policy (SWRCB, 2004a). The enforcement policy describes how the several regulatory tools available to the SWRCB and RWQCBs will be used to ensure compliance with regulatory requirements.

Regulatory Tools

Regulatory tools can be broadly classified as compliance options and enforcement options. A number of regulatory and non-regulatory tools are available to ensure compliance. Some of the more significant compliance options include:

- Waste Discharge Requirements (WDRs)
- Waivers of WDRs
- National Pollutant Discharge Elimination System (NPDES) Permits

[2] In California the SWRCB has the authority under a delegation agreement with U.S. EPA to implement the NPDES permitting requirements of the Clean Water Act.

- Total Maximum Daily Loads (TMDLs)
- Management Agency Agreements
- Cooperative Programs

A complete description of these options is beyond the scope of this paper. Further information can be obtained from the NPS Implementation and Enforcement Policy and from the SWRCB web site at www.waterboards.ca.gov.

Enforcement options are used when compliance options are not effective in protecting water quality. The SWRCB's enforcement policy is described in SWRCB, 2002 and SWRCB, 2004a. Some of the more significant enforcement options include:

- Notice of Violation
- Cleanup and Abatement Order
- Cease and Desist Order
- Administrative Civil Liability Order
- Prohibition of Discharge
- Referral to the Attorney General

Again, a complete description of these options is beyond the scope of this paper. However, for less serious offenses, there is normally a progressive response from the Notice of Violation (essentially a formal letter requesting compliance) to a Prohibition of Discharge that may require a discharger to cease operations. The SWRCB and RWQCBs can start at any place in the series, but generally try to use the minimum resources to accomplish the objective. Involving attorneys generally increases the cost to both the discharger and the State, and does not ensure compliance with water quality objectives.

Waste Discharge Requirements and Waivers of WDRs

WDRs and waivers of WDRs are the principle regulatory tools under State law. WDRs are the requirements or conditions prescribed by an RWQCB to protect the beneficial uses of receiving waters from an existing, proposed or potential discharge. Waivers of WDRs may be for an individual discharge or for a certain type of discharge. They are generally issued for discharges that pose a minimal threat to the environment, but can be structured like a permit or WDR. To date, the RWQCBs have adopted waivers for about 48 categories of discharge. These include everything from emptying a backyard swimming pool to using a septic tank.

Waivers are not new; they've been used in California for over 30 years. They were developed because it is not possible to provide a high level of regulatory oversight of every discharge in California. For agricultural discharges alone this would require numerous permit writers and inspectors. Knowing this, the legislature modified the Water Code in 1969 to provide for the conditional waiver of WDRs if a Regional Board finds that the waiver is not against the public interest. Waivers are not exemptions from compliance with water quality objectives. They are conditional and (contrary to some press reports) have always been conditional. Enforcement action can be taken for violation of conditions.

SB 390
Senate Bill 390 was signed into law in October 1999 and changed Water Code Section 13269 to require:

- Renewal of waiver policies and individual waivers by January 1, 2003;
- Review of the terms of the waiver policy at a public hearing;
- Determination of whether the discharge should be subject to general or individual WDRs;
- Renewal/termination of waivers every five years;
- Enforcement of waivers;
- Minimum penalties for violations

In 1982 the Central Valley RWQCB (1982) adopted a waiver for 23 categories of waste discharge including agricultural runoff. Due to insufficient resources, the RWQCB was unable to verify that dischargers were complying with the waiver; thus, the waiver was largely a passive program. Pursuant to SB 390, the 1982 waiver expired on January 1, 2003. The RWQCB has since adopted new waivers for individual dischargers and "coalitions" that fully meet the requirements of SB 390. Waiver programs are also being developed in other regions, but the vast majority of dischargers and discharges is in the Central Valley.

Creative Solutions
It's been said that water quality regulation is a ratchet; i.e., it tends to become more rigorous and structured, not less so. Given the increased pressures on the environment and natural resources from a continually expanding population, it is perhaps understandable. This trend toward increased regulatory oversight has not been accompanied by increased resources for implementation.

Developing workable solutions to complex water quality problems under the conditions presented in this paper requires a high degree of creativity and innovation. It also requires full participation by the regulated community. With so many discharges on the landscape it could be easy for some dischargers to escape regulation. One of the greatest challenges facing the SWRCB and RWQCBs is how to ensure full participation.

Waiver programs utilizing cooperative approaches among dischargers (as opposed to individual waivers or WDRs) are the most efficient and cost-effective means of compliance for both the State and growers. It's very important for growers to participate because the alternatives can be much more onerous and costly, for both the grower and the State. SB 390 requires the RWQCBs to make a determination whether or not discharges should be subject to WDRs. If cooperative programs don't work, if growers don't join and support their coalitions or enroll by whatever means provided by their RWQCB, the regulatory ratchet will move up a notch and there could be unintended consequences by way of increased regulatory oversight.

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The Changing Culture In Rural Water Quality Management

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The Sacramento Valley Water Quality Coalition (Coalition) was formed in 2003 and has since made tremendous strides to improve and enhance water quality in the Sacramento River Basin, the northern part of California's great Central Valley. As representatives and students of the Coalition and rural California, it is important that we step back periodically and evaluate why these strides have been made and the context in which these seminal water quality programs have emerged in the Central Valley. Most notably, there have been many important lessons learned along the way that reflect a progressive and changing dynamic in rural California. This paper attempts to capture this changing dynamic and to describe the deeper philosophies that are imbedded in the Central Valley's rural fabric.

We will first describe the backdrop against which the Coalition emerged and how it was formed and organized to improve and enhance water quality in the Sacramento River Basin. We will not specifically address the regulatory program established by the State Water Resources Control Board (SWRCB) and the Regional Water Quality Control Board (RWQCB), although this regulatory program has played a significant role in shaping the Coalition efforts and we hope will benefit from this discussion and many of the recommendations described below. Instead, we will explain the dynamic in the Sacramento River Basin and through this lens, offer broad recommendations on how we believe rural communities can best work in a positive--non-confrontational--direction to achieve sound water quality goals.

Integrated Water Management in the Sacramento Valley

The history of water in the Sacramento Valley from geologic time to the gold rush and then to the present is fascinating and worth further reading. For our purposes today, it is important to start with the significant changes that began in the Sacramento Valley during the early 1990s when California was in the middle of a prolonged drought. Although the 1976-77 drought was sharper, the longer drought from 1988 to 1994 revealed certain vulnerabilities in California water management that led to important changes, many of which dominate the water landscape today.

It was during this time that Governor Wilson, rather than declare an emergency, created the Drought Water Bank (largely focused on the Sacramento Valley) to help meet water supplies in California. The Endangered Species Acts also came to a head in federal and state court regarding diversions off the Sacramento River and Congress, the State Legislature and Counties took various actions to respond to the drought. Quite simply, these cumulative actions led to changes in the way the Sacramento Valley viewed and thereafter tackled water management.

What ensued was one of the most aggressive fish passage improvement programs in the world where water districts, companies and individuals installed fish screens, siphons, fish ladders and habitat improvements. These improvements have led to important trends for the recovery of salmon and other fish in the region, while helping to assure water for farms, waterfowl and other terrestrial species. Additionally, during this time a group of water right holders with settlement contracts with the Bureau of Reclamation developed a Basin-Wide Management Plan to avoid litigation. This, in turn, provided a framework for the Sacramento Valley Water Management Program (SVWMP)(see www.norcalwater.org) and new creative ways to protect water rights in the Sacramento Valley while helping to meet water quality standards in the Bay-Delta as required by the SWRCB Water Quality Control Plan. Most notably, these programs and many similar efforts in the Sacramento Valley began to coalesce as an integrated water management program with water quality improvements as an important component.

The Sacramento Valley Water Quality Coalition

The seeds for the Sacramento Valley Water Quality Coalition were planted in 2001 as agricultural leaders in the Sacramento Valley recognized the challenges that lay ahead related to managing water quality issues. The RWQCB had found the Sacramento and Feather Rivers impaired for diazinon and it was in the process of designating Bay-Delta tributaries and sloughs as toxic hot spots under California law. Additionally, the Legislature, in fall of 1999, had passed SB 390 to rescind the existing waiver of waste discharge requirement programs by the end of 2002, including the agricultural waivers.

As coalition groups around the Central Valley were organizing, Sacramento Valley leaders looked for models to address water quality in a rural setting. In the Sacramento Valley, we had the benefit of the California Rice Commission (CRC) and its Rice Pesticides Program that started in 1986. It is generally recognized that this program had effectively addressed water quality concerns with rice pesticides. We also had the benefit of the partnerships, most visibly between water users and Ducks Unlimited, that had successfully restored record fish numbers on Butte Creek and others streams in the Central Valley and had helped restore waterfowl populations along the Pacific Flyway. We also worked with and shared ideas with the leaders in the San Joaquin Valley, who were continuing their efforts to manage water quality issues in a different, although closely related environment in the Central Valley. Fortunately, many of the Coalition leaders had participated nearly a decade ago in developing an agricultural water quality program for California's Central Coast.

The Coalition members explored many types of institutional approaches. For example, the Coalition explored having commodity organizations develop programs like the California Rice Commission, but recognized that, unlike the rice program, which has a fairly unique set of pesticides for a water emergent crop, many of the constituents of concern were spread across various commodities and could not be addressed by a single commodity organization.

Although the SWRCB and Regional Board saw water districts and companies as logical entities to manage water quality programs, the Coalition members in the Sacramento Valley made it clear that water districts and companies make water supply decisions, whereas most of the water quality decisions are basically land use decisions made by individual growers and wetlands managers working with their Pest Control Advisors (PCA's) and Agricultural Commissioners. As such, the Coalition members believed that there needed to be a more direct link between water quality concerns and the agronomic decisions.

What emerged was a nested watershed approach where a macro-level watershed group (the Coalition) formed along geographic boundaries that coincide with the RWQCB's Basin Plan. Nested within the Coalition, Subwatershed Groups formed and took actions necessary for their particular area to improve water quality and to meet specific regulatory obligations. In 2003, more than 200 entities in the region committed to this approach and formally joined the Coalition. This approach captures the efficiency and collective spirit provided by a larger macro-watershed group, while keeping the ultimate decisions affecting water quality close to the ground at the local, subwatershed level.

The Coalition's "Regional Plan for Action" (Regional Plan) has served and will continue to serve as the roadmap for the Coalition by describing a watershed approach for the Sacramento Valley. Developed in

June 2003, the Regional Plan will continue to help the Coalition implement the SWRCB and RWQCB Strategic Plan by concentrating on entire watersheds rather than focus on specific constituents. The Plan also carries out the Watershed Management Initiative, which specifically recognizes the Sacramento River Basin as a management area or "watershed."

The Regional Plan has utilized a scientific approach to conduct water quality sampling and analyses, prepare timely and comprehensive reports, implement and evaluate management practices, and establish effective educational programs. As required by the RWQCB regulations, the first step in the Plan was the development of a Watershed Evaluation Report (WER) and then a detailed Monitoring and Reporting Program Plan (MRPP). The WER is a comprehensive watershed assessment prepared by local agricultural representatives, wetlands managers and natural resource professionals. The WER provides a detailed description of the landscape in each of the ten Coalition subwatershed areas, including cropping patterns, soil quality, water quality issues, management practices implementation, and pesticide use.

The ultimate output of the WER is a drainage prioritization table for each subwatershed. Using the DWR Land-Use Survey Data, the twenty-one county region was divided into nearly 250 geographic areas. The Coalition evaluated raw acreage numbers for orchard, annual and pasture crops respectively in each drainage area and then multiplied these raw acreages by a "weighting factor" with orchards receiving the greatest emphasis and pasture the least. Adding each of these weighted acreages in each subwatershed produced an index that was used as the primary criterion for ranking a drainage area. The Coalition also evaluated diazinon, chlorpyrifos, copper and pyrethroid use in each drainage area and used this data as the second criterion. The third criterion was the existence of impaired waterbodies listed under the so-called 303(d) list. Each subwatershed group then evaluated the ranked drainages in their subwatershed and based upon their local knowledge of the hydrology and current issues, selected monitoring sites for the initial sampling.

Moving to the present, the Coalition and ten Subwatershed Groups have signed a Memorandum of Agreement (MOA) that defines the respective roles and responsibilities of the Subwatershed Groups, as well as the Northern California Water Association, Ducks Unlimited and the Coalition for Urban Rural Environmental Stewardship, to implement the Regional Plan, including the roles of consultants that will assist in this process. Additionally, the Coalition has signed a Memorandum of Agreement (MOU) with the California Rice Commission to coordinate the respective programs in the Sacramento River Basin. The Coalition is considering partnerships with municipalities and urban areas in the region that are developing stormwater management plans and facing increasingly more stringent effluent limitations.

Recommendations for Successful Rural Water Quality Programs

As the Coalition continues its efforts to improve and enhance water quality within the current regulatory framework, we offer initial recommendations to help assure that these programs will be successful. Many of these recommendations may seem self- evident, but we feel they need to be mentioned because the consequences for ignoring them can set back improvements in water quality. Conversely, we believe that following these recommendations will help accelerate any progress necessary to address water quality problems.

Recognize the distinction between point and non-point source pollution. The important distinction between point source and non-point source pollution control in the United States and California has been muddied over the past years. We recommend that this distinction must be respected and clarified and that every decision involving water quality regulations must recognize this distinction.

The federal Clean Water Act and the Porter-Cologne Water Quality Control Act recognize the important practical differences between point and non-point sources, and further recognize that a different regulatory framework is necessary for non-point sources. In 1972, Congress defined point source pollution in the Clean Water Act as that which comes from a discrete conveyance and noted that all other sources that did not fit such a definition were considered non-point sources. At the same time, Congress asked the Environmental Protection Agency to adopt guidance regarding non-point source control and required states to develop waste treatment management plans. This distinction was critical from the regulatory perspective, as the Federal government took the responsibility to regulate point sources through the National Pollution Discharge Elimination System Program and reserved regulation of non-point sources to the State and local governments through adoption of area-wide management plans as prescribed in the Clean Water Act. While agricultural return flows were initially treated as point sources, Congress exempted these sources from the NPDES requirements and subjected them to alternative regulations focused on issue identification, initial planning measures and voluntary programs to manage non-point sources.

In 1987, Congress amended the Clean Water Act to more aggressively address non-point sources by adding Section 319 thereby requiring states to develop non-point source management programs, including identification and implementation of best management practices to control non-point source pollution. Section 319 clearly acknowledges the complexity of controlling non-point source pollution and qualifies the requirement to identify and implement management practices by stating that the practices should be selected to reduce pollution to the "maximum extent practicable." EPA has provided guidance documents regarding structural and managerial measures States may utilize in their non-point source programs.

The SWRCB has adopted a Non-point Source Program consistent with Section 319. The SWRCB and RWQCB should now implement its Conditional Waiver Program for Agricultural Discharges in a manner that respects these policies and programs. As outlined in Gary Carlton's paper in these proceedings (*Water Quality and Agriculture: the Big Picture)*, guidance is provided in California Water Code Section 13369, which notes that California's non-point sources management program includes a three-tiered regulatory approach for promoting implementation of management practices.

Understand the rural culture in the region. The key to successful water programs is an understanding of the rural culture and the human dimension. The Sacramento Valley, as an area with rich water supplies, is a senior water rights culture with numerous area of origin provisions designed to protect water supplies for this region into the future. As such, the Sacramento Valley is driven by a sacred vision that both present and future water needs will be met in the region for farms, waterfowl, fish, cities and rural communities. There have been many efforts during the past half-century to redirect water from this region, which has led to confrontation and in many cases litigation. Future efforts to redirect water will also receive vehement opposition.

On the other hand, the positive energy that has developed in the Sacramento Valley over the past decade, whether for fish passage or the SVWMP, is all built upon the strong recognition and protection of these water rights. The positive actions by the Coalition are built on the same foundation. Other regions also have a distinct culture, that, when well understood, will lead to innovative solutions.

Preserve the important physical assets within a region. In addition to the human dimension, every region has unique and interdependent geographic attributes. The Sacramento Valley is a unique pallet of farmlands, waterfowl habitat and spawning grounds for numerous fish species, as well as the water supply source for much of California. Those living and working within this region want to preserve these important attributes and to maintain this unique working and natural landscape. As a result, a regional approach is necessary to not only recognize the unique nature of this region (and others), but to also shape water quality policies that reflect these attributes.

Facilitate the ways rural areas organize. The way in which local parties join together with a common mission is very powerful and should be facilitated. This is particularly true in rural areas where citizens tend to be very independent and averse to being a part of organizations. Additionally, there are many rural areas that are not located within an existing municipality or special district. It is therefore important to recognize that rural areas organize and govern very differently than urban areas and efforts to force urban governance on rural areas is not productive and is doomed for failure.

In the Sacramento Valley, partnerships are the foundation for the regional programs and the way people and entities organize. The Coalition was formed organically in the Sacramento Valley and is now organized around an agreement articulating the unique partnerships and respective roles within the region. This type of organic organization should be encouraged.

Link regulatory programs and watershed efforts to local decision-makers. As previously discussed with respect to the formation of the Coalition, it is key to create the appropriate linkages to decision-makers. In the Sacramento Valley, most of the decisions affecting water quality are agronomic decisions made by growers and wetlands managers, in consultation with their Pest Control Advisors (PCA), University of California Extension, the local Agricultural Commissioner's office in each County and the Natural Resources Conservation Service. As a result, the decisions should be focused in the appropriate places. Efforts should be avoided that thrust other entities (i.e., water suppliers) into this framework that do not have the appropriate decision-making authority. All outreach and other activities also should be focused in the appropriate arenas to assure these efforts are effective.

Focus energy in the appropriate places. Over the past several years too much energy has been expended looking for water quality problems rather than addressing known water quality problems. A certain amount of this energy will be expended in a new program, but as we move forward, it will be more important to focus limited resources, both human and capital, in those areas where there is a high likelihood of a water quality problem. The Coalition recognizes the need to efficiently manage resources and prioritized drainage areas based upon their potential to impact water quality. This will help focus energy. For example, the drainage area ranking described above directly influences sampling location decisions made by working groups at the subwatershed level. This effort will establish a baseline set of data on important waterbodies and provides a vision for future efforts in other drainage areas.

The Role of Water Quality Monitoring at the Watershed Level

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Introduction

Water quality monitoring at the watershed level has been the backbone of numerous efforts to understand and manage surface water quality for the last several decades. This paper discusses the intent of water quality monitoring at a watershed level and how it is fundamental to managing surface water quality in California. The paper is set against the backdrop of the current monitoring programs spawned by the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands within the Central Valley.

Three important goals of monitoring at the watershed level will be discussed: 1) assessing "condition" of the water body, 2) pollutant source identification, and 3) monitoring the effectiveness of source control measures to enhance water quality. The sampling design (location of monitoring sites) and monitoring strategy (timing, frequency of monitoring, and monitoring components used) should change depending on which of these goals is the focus of a monitoring program. Taking a "one size fits all" approach to monitoring can compromise the ability of the monitoring program to generate the information necessary to adequately meet the goals of the program.

Intent of Watershed Level Monitoring

Watersheds can be any size and consist of all surface water draining to a designated point. In locations with topographic relief, watersheds are usually easy to define. In regions like the Central Valley, low topographic relief and an extensive network of water delivery and drainage conveyances make watersheds difficult to define. Watersheds today may be best described as a community of landowners and operators who share the same water resources and who work cooperatively to be stewards of water quality.

Monitoring water quality at the level of the watershed is a fundamental part of water quality stewardship. In fact, the watershed is the only appropriate level to monitor for non-point source inputs to surface water bodies. In addition, watershed level monitoring allows for the most effective use of scarce human and fiscal resources. The information generated is used to determine if a water quality issue is present, and if so, what is the nature and extent of the issue. Watershed level monitoring should be designed to identify any potential water quality issue so that it can be addressed.

Assessing Condition

Monitoring programs designed to assess condition may be focused on water bodies located over a very large region or alternatively, it is possible to target specific watersheds and monitor the condition of those water bodies. The latter approach is probably the most common form of monitoring with examples including programs such as the Central Valley Regional Water Quality Control Board's (CVRWQCB) Organophosphate Total Maximum Daily Load monitoring program and the USGS National Water Quality Assessment Program (NAWQA). Permanent sites are established and visited at regular intervals for sample collection. These programs often have the goal of developing long-term data sets that can be used to evaluate trends in water quality against the backdrop of natural environmental variation. Sample sites can be located at the base of watersheds, and a few sites may be adequate to assess general condition of the water body in the entire watershed.

Monitoring Components to Assess Condition of a Water Body
There can be any or all of several components to a monitoring program including analysis of water chemistry, water column (water in the water body) toxicity, sediment chemistry, sediment toxicity, and bioassessment. Each of these can provide complimentary pieces of information about the condition of the watershed and water body, and are generally used in combination.

Water Chemistry Analysis

Water chemistry provides an instantaneous measure of the condition of a water body at a single site and the data reflect conditions only at that site at that time. Water chemistry can include *in-situ* measurements such as temperature, pH, dissolved oxygen, or conductivity. It can also include laboratory measurements of nutrients, bacteria or concentrations of specific contaminants (e.g.,selenium or organophosphate pesticides). Measurements are often expressed in terms of loads. Load combines the measures of concentration and discharge volume of water and is a measure of the amount of a constituent that passes by a site in the water body. Samples for chemical analysis are easy to obtain and usually involve either inserting a probe into the water and recording the observations, or collecting water in a container to be delivered to a laboratory for analysis.

Laboratory analytical techniques and quality control are well established. Analytical costs vary depending on the number of constituents selected for measurement, and the detection limits desired (the lowest concentration that an instrument is able to detect and reliably measure). The lower the detection limit, the higher the cost. Often it is necessary to measure contaminants at very low concentrations because adverse biological effects in test organisms have been detected at those low concentrations. In California, some detection limits are below the capabilities of many analytical laboratories. Some simple measurements (e.g., temperature and dissolved oxygen) can be collected continuously using specialized instruments left in the water, but these instruments tend to be subject to fouling, vandalism, and equipment loss, and data are often suspect.

Often, results from water chemistry analysis are compared to established water quality criteria to develop conclusions about watershed condition. For water quality data, these criteria are often developed from dose-response laboratory toxicity studies and do not reflect actual conditions of the water. For example, large quantities of organic carbon in the water column can bind to many contaminants making them unavailable to cause toxic effects in organisms. This bioavailability issue often requires that dissolved and bound fractions of contaminants be measured separately to adequately determine whether the contaminants in the water could be problematic. If dissolved and bound fractions are measured together, the water chemistry results may indicate an exceedance of a water quality criterion, while that same water used in a water column toxicity test does not result in toxicity to the test organisms. Achieving a comprehensive understanding and temporal coverage of water chemistry in a watershed can become expensive because of the need to sample at numerous locations and at several different periods of time. Also, monitoring often targets a class of constituents to minimize analytical costs, and if other contaminants are present, they may go undetected.

Water Column Toxicity Testing and Toxicity Identification Evaluation (TIE's)

Toxicity testing has become a primary tool for many water quality management programs because the testing is ecologically relevant, and bioavailability is directly measured. For example, if the water is toxic, contaminants are in the dissolved phase and are taken up by organisms. The U.S. EPA has numerous publications documenting the validity of toxicity testing in predicting adverse ecological impacts to resident biota in water bodies. Testing can either be for acute (U.S. EPA 2002a) or chronic effects (U.S. EPA 2002b), the difference in the tests being a function of the time the test organisms spend in the sample water.

For the CVRWQCB Conditional Waiver Monitoring Program, three species are tested representing three different trophic levels, primary producer (the green algae *Selanastrum capricornutum*), primary consumer (the water flea *Ceriodaphnia dubia*), and predator (the fathead minnow *Pimephales promelas*). Other species may be used if appropriate. The fathead minnow is tested in its larval stage. Using all three species in toxicity testing is designed to catch all potential classes of constituents that may be toxic to resident biota, as each group is sensitive to a different (although overlapping) set of contaminants. These three species are used across the entire United States despite the fact that they are rarely found in a watershed where the water samples are collected. However, they are sensitive indicators of toxicity, and are easily maintained in a laboratory setting. It is assumed that if toxicity is present for any of these three species, the water will be toxic to the resident biota in the water body. The methodology published by the U.S. EPA is extremely well developed with rigorous quality control and statistical procedures for analysis of the data.

If organism survival or reproduction is low relative to the laboratory controls, the cause of the toxicity is unknown. Causation may be established by performing a Toxicity Identification Evaluation (TIE). These tests are performed in phases and to confidently identify a cause(s), all three phases are necessary. Phase I involves identifying a general class of contaminant responsible for the toxicity. It usually involves physically or chemically manipulating the water sample to remove specific potential sources of toxicity. After each class of contaminant is removed, the toxicity test is repeated and if the toxicity no longer exists, the contaminant class previously removed is assumed to be the cause of the observed toxicity. Phase II involves the identification of a specific contaminant and the procedures used depend on the type of contaminant suspected as the toxic agent. Phase III is a confirmatory analysis and can involve a series of steps including spiking the sample with the putative toxic chemical. At the end of the three phases of a TIE, sufficient information is generally available to identify the specific contaminant causing the toxicity. However, it is not uncommon to complete the first phase of a TIE and be unable to identify a specific class of contaminant responsible for the toxicity. In this case, the cause is usually assigned to "unknown toxicity". Cost for the TIE's vary depending on the exact sequence of tests. It is possible that the analysis can cost $10,000 if a sample is moved through the complete set of TIE tests.

Sediment Chemistry and Toxicity Testing

Sediment chemistry and sediment toxicity tests are similar to water chemistry and toxicity tests. Sediment chemistry is usually performed on sediment pore water, the water that is located in the interstitial spaces between sediment particles. It is this pore water that contains the dissolved, and therefore bioavailable, fraction of the contaminant(s). Once pore water is separated from the sediment, it can be analyzed for the same classes of constituents as water collected from the water column. Costs for chemical analysis of pore water are similar to costs for standard water chemistry. However, sediment tends not to change rapidly (unless significant runoff events delivering sediment occur often) and testing can occur less frequently.

Sediment toxicity can be evaluated using either pore water or intact sediments. If a sufficient quantity of pore water can be obtained, toxicity tests can be performed on the sample in the exact same manner as with water collected from the water column. U.S. EPA protocols for intact sediment toxicity testing allow several organisms to be used, but for samples collected in the Central Valley, two organisms, an amphipod (*Hyaella azteca*), and larval fly (*Chironomus tentans*), are the primary test organisms. These species are broadly distributed and are found naturally in the Central Valley. They live directly on or in the sediment and are exposed to the contaminants in the pore water. Sampling techniques can vary from collecting sediment cores, dredge samples, or simply removing the top layer of sediment with a stainless steel scoop. Generally, fine sediments are used in the toxicity tests, as coarse sediments tend to consist of sand and retain very few contaminants.

Sediment TIE's are still being developed and tend to be slightly different across laboratories. TIE's on pore water are performed similarly to water column TIE's, but TIE's on intact sediment are not yet standardized. TIE's on intact sediment involve mixing various compounds into the sediment to remove classes of contaminants prior to retesting. Costs vary with the exact procedures used, but can be several thousand dollars per sample. Often, sediment toxicity tests are performed in conjunction with sediment chemistry and the cause of toxicity is assigned to any or all of the contaminants detected in the sample without performing sediment TIE's.

Bioassessment

Bioassessment is the newest tool for monitoring and is becoming increasingly common within California. Bioassessment uses biological indicators, typically benthic macroinvertebrates or fish, to evaluate water body condition. Bioassessment integrates the water quality signal over time and reflects ecological reality. Bioassessment involves sampling the fish or bottom dwelling invertebrates and developing measures of water body condition. However, constraints currently exist when using bioassessment in California.

In California, there are too few fish species to develop adequate measures of water quality, so the bioassessment tools rely on bottom-dwelling invertebrates. Pristine sites are used to establish reference conditions that can be compared to sites suspected of being impaired. However, because pristine sites are not available in many California locations such as the Central Valley, using bioassessment data to arrive at conclusions about the condition of the water body is currently not possible. Additionally, for those locations where bioassessment indicates poor condition, the bioassessment data cannot be used to establish the causal factor(s). It is also critical that habitat data be collected at the time the biota are collected in order to disentangle the effects of degraded habitat from the contaminants as the primary factor causing degradation of biotic communities.

Because reference sites are not available in the Central Valley, bioassessment is currently encouraged but not required by the CVRWQCB as part of the Coalition's Conditional Waiver monitoring programs. Bioassessment is being performed by a single coalition at a location with a long-term data set where trends can be determined.

Pollutant Source Identification

A large number of monitoring programs wish to identify the source(s) of any contaminants in the water body so that appropriate management actions can be implemented and the source(s) controlled (see below for monitoring effectiveness of source control). This is a focus of the current Conditional Waiver for Irrigated Agriculture Monitoring program. Unfortunately, unless there is a single source for specific contaminants, source identification is essentially impossible, especially if the goal is to associate contaminants with individual parcels of land. The problem becomes more challenging as the size of the watershed increases. The spatial variation in environmental conditions such as soils, slope, soil moisture, water application practices, and soil organic content coupled with the temporal variation in factors such as rainfall and temperature tend to obscure the ability to associate a water quality signal with a specific location at the scale of the watershed.

Consequently, use of a Geographic Information System (GIS) is almost as important in source identification as is the monitoring component itself. A GIS is a computerized mapping and data analysis system that allows individual parcels of land with its associated attributes (e.g., crop, pesticide applications, soil type) to be mapped exactly. With a GIS, the potential sources can be narrowed down and source controls measures can be recommended for specific parcels. Detailed information is required on the contaminant such as application rates, application site(s) and dates, irrigation/rainfall event data (timing and amount), and chemical properties of the constituent (i.e. half-life under relevant conditions, and solubility or adsorptive characteristics (K_{oc})). Also, GIS may assist Phase I of the TIE's by providing information that narrows the prospective contaminants based upon the land use records and associated attributes.

Some of these data are available through Pesticide Use Reports filed with the County Agricultural Commissioners. Other than a GIS, the only monitoring components potentially capable of identifying sources are water quality analysis and water column toxicity testing with associated TIEs. Sediment chemistry and sediment toxicity generally cannot be used to identify sources, as it is difficult to know the residence time of sediment at any location in the watershed. While the half-life of many pesticides is relatively short, it is often longer than the time between runoff events, which can potentially transport sediment from parcels to the water body and then downstream. Bioassessment techniques cannot be used to identify sources as there are very few guidelines relating the presence or absence of specific organisms to specific contaminants, consequently, no sources can be determined.

The appropriate method to identify the location of inputs of contaminants is to move from upstream to downstream in a Lagrangian sampling design. The underlying concept behind the Lagrangian design is that the same bolus of water is sampled as it moves downstream and picks up additional sources of contaminants. Moving upstream samples different portions of the hydrograph and chemograph and can lead to erroneous conclusions about the source of contaminants. This is particularly true during periods of low flow when stream reaches may gain or lose water as a result of exchange of water between the surface and subsurface of the water body.

Monitoring Effectiveness of Source Controls

Source control efforts follow after using a combination of GIS, water chemistry analysis, water column testing and TIE's to identify the contaminant(s) of concern. Implementation of a management practice or a set of practices can be undertaken in an attempt to reduce inputs to surface waters. However, determining efficacy of these practices at the level of the watershed is very difficult to do. Reliable conclusions about differences in water quality generally require the use of inferential statistics to test hypotheses of no change or change in water quality. For single point source with known location of input, the Before-After, Control-Impact (BACI) design was developed to evaluate changes in water quality above and below the input (e.g., Stewart-Oaten and Bence 2001). Unfortunately, if there are numerous management practices implemented in the watershed with numerous points of entry into the water body as is common in irrigated agriculture, the statistical framework for analysis is not well developed. And, if the points of entry into the system are unknown (e.g. seepage, unknown points of surface discharge), it is not possible to establish upstream and downstream sampling points.

Monitoring the efficacy of management practices to improve water quality can be attempted at the watershed level as long as the challenges outlined above are recognized. In many cases, monitoring to evaluate the effectiveness of a management practice or suite of management practices is more appropriate at the farm or field level.

Conclusions

Monitoring at the level of the watershed has moved from single monitoring components to multiple measures of condition. Typically, monitoring programs incorporate at least two components although water chemistry analysis is often the component common to different programs. While two or more components can help narrow the potential causes for degradation of condition, they can also lead to opposite conclusions. This problem is often resolved by using best professional judgment, which negates the results of one of the monitoring components.

Managing California's surface water quality is complex and challenging. Monitoring programs must balance agricultural, environmental, and urban interests and recognize constraints on human and fiscal resources. Water quality monitoring at a watershed level is fundamental to a program like the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands within the Central Valley. Both the Central Valley Regional Water Quality Control Board and the Coalitions struggle with the human and fiscal constraints in their efforts to develop effective monitoring programs. All groups recognize that a "one size fits all" approach to monitoring may compromise their ability to meet the goals of the program.

A few sites located at the base of a priority watershed may be cost-effective and adequate to assess the general condition of a water body and enable more resources for temporal coverage in data collection. Water chemistry, toxicity testing, sediment chemistry and sediment toxicity testing are important monitoring components used in assessing the condition of a water body. Each component provides different information and they should be used in combination to assess condition of the water body. However, it is possible that different components provide conflicting information about the condition. Inclusion of a GIS component may be as important as water quality monitoring when identifying the source of a constituent of concern. Attempts can be made at a watershed level to evaluate the effectiveness of management practices to address a specific water quality issue, but the complex nature of non-point source pollution will challenge this approach. There may be instances where water quality monitoring at the farm level will be necessary to evaluate management practices for improving water quality.

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Water Quality Monitoring at the Farm Level

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Introduction

Development of an informative water quality monitoring program starts with the establishment of clear monitoring questions. The appropriate spatial scales selected for monitoring are dependent upon these questions. Watershed scale monitoring can be implemented for a suite of purposes. For instance, a watershed group might decide to use watershed scale monitoring to quantify relative pollutant contributions from sub-watersheds dominated by agricultural versus urban land uses.

The results of watershed scale monitoring often stimulate regulators, farm managers and stakeholders to pose farm scale water quality questions. Typical farm scale questions include: 1) how does the magnitude of pollutant contribution differ between agricultural enterprises (*e.g.*, rice, corn) and individual farms; 2) what agricultural management practices are associated with increased or decreased pollutant loading; and 3) how effective are water quality improvement practices at reducing pollutant loads from farms once adopted. Farm managers have specific interest in knowing the magnitude of pollutant discharge from their farm as well as from the fields they manage on that farm. This information can aid them in determining: 1) if their management is generating relatively high or low pollutant loads; and 2) the efficient allocation of limited resources among fields to reduce total discharge from the farm. Continued monitoring after implementation of water quality improvement practices at the farm level is a critical component of the adaptive management process.

The objective of this presentation is to illustrate the types of farm specific information and management guidance which can be derived from farm level water quality monitoring. To accomplish this objective we report a synthesis of monitoring from coastal dairies (Lewis et al., In Press) and stream diversion dependent irrigated pasture systems (Tate et al., In Press) in northern California.

Case Study 1 – Tomales Bay Dairies

In the Northern California coastal watershed of Tomales Bay, entities such as the San Francisco Bay Regional Water Quality Control Board and the National Shellfish Sanitation Program Model Ordinance are requiring dairy farms to minimize their discharges of fecal coliforms into tributaries and ephemeral streams draining into the Bay. Each dairy property is unique and comprised of a complex set of management units such as pastures, milking barns, loafing areas, dry lots, and manure storage facilities.

The dairy manager's water quality data needs are generally at a scale that matches these units, which is smaller than that provided by sub-watershed scale microbial source tracking monitoring methods previously employed in the watershed. In order to assist these dairy owners in developing a targeted remediation plan, we conducted an on-farm monitoring program that matched water quality data to the spatial scale of these on-farm management units. Our objective was to demonstrate that an appropriately scaled monitoring method would generate water quality data that would guide land owners as to which specific land use practices are contributing the greatest pollutant loads on their property and thereby help prioritize which management practices would need to be modified to help meet the water quality objectives for the Bay.

Ten dairies within the Tomales Bay watershed were enrolled in the study and sampled over 2 rainfall seasons. Water quality samples were collected on a storm event basis from loading units that included: 1) manure management systems into which manure is flushed and stored; 2) gutters and storm drains which collect rain runoff from building roofs and direct it into streams; 3) pastures in which cattle graze; and 4) corrals and lots where cattle are held prior to and after milking or for exercise. In-stream samples were collected above and below the dairy facilities to document overall dairy impact on instream fecal coliform levels.

Upstream and downstream results confirm that significant (1 to 3 $\log_{10}$) increases in fecal coliform concentration and load occur immediately below a dairy facility. Within dairy management unit results illustrate patterns of fecal coliform concentration and loading amounts that are useful to prioritize remediation activities. High concentrations and loads for the fecal material captured within the manure management system emphasized the value and importance of a functioning system to capture and store the material with the greatest potential to load fecal coliform to surface waters. Outside of those systems, dairy managers would get the greatest reduction in fecal coliform loading through reduction of concentrations and runoff generated from lots and stockpiles. Following lots and stockpiles attention should be given to pastures. Concentration and load values from gutters are similar to those identified in upstream and control units indicating that, if this water can be kept separate from manure sources, it can be directed back into surface waterways.

Case Study 2 – Irrigated Mountain Pastures

Irrigated pasture in northern California provide critical summer forage for livestock. In many of these systems, water is diverted directly from a stream into ditches or pipes and transported to individual pastures where it is applied as flood surface irrigation. It is common to have a significant amount of runoff generated from pastures during flood irrigation events. During the 2004 irrigation season we collected pasture level water quality data from 10 stream diversion and return based pasture irrigation systems located in Modoc and Lassen County, CA. Our objectives were to: 1) illustrate a farm level assessment and monitoring approach for pasture managers and natural resources professionals working on this issue; and 2) identify relationships between downstream increases in key pollutants and pasture irrigation and grazing management practices.

On each ranch, sampling locations were established and sampled bi-monthly to provide water quality and flow volume data from: 1) each creek above the irrigation diversion; 2) pasture surface runoff ditches and swales immediately above the return of pasture runoff to the natural stream channel; and 3) each creek below all pasture runoff. This sampling strategy allowed us to: 1) examine above and below instream water quality changes due to the irrigation activity; 2) examine changes in water quality as irrigation water passes across pastures; 3) account for differences in flow volume for each water source (instream – above, pasture runoff, and instream – below); and 4) account for changes in water quality and flow over the course of the ~2 month irrigation season.

We found relatively small increases in nutrient levels below versus above these systems. Increased concentrations of potassium and sulfate were observed below the irrigated pasture return, which does not likely represent a water quality problem but does indicate the loss of important plant required nutrients from the pastures. Our data indicate that mineral nitrogen levels are low in these streams and pastures with nitrate and ammonium an order of magnitude below levels of water quality concern. Given the relatively low fertility of these systems and low to no fertilizer application rates, it is not surprising that nutrient levels are low in runoff. However, *E. coli* concentration and load increased by several orders of magnitude below several pasture systems and illustrates that significant microbial pollution is possible due to grazed irrigated pasture management. Of particular value to the manager is site specific information on how irrigation management decisions are linked to agricultural discharge quality and potential water quality degradation. We found that *E. coli* concentration and load increased significantly as: 1) irrigation application rate and resulting pasture runoff levels increased; 2) cattle stocking rate within the pasture increased; 3) the timing of irrigation coincided with the timing of cattle in the pasture; and 4) as the percentage of streamflow diverted for irrigation increased. All of these factors are within the control of the manager and can be modified to reduce water quality impact.

Summary

Farm scale water quality monitoring can be used to determine farm level management effects on water quality, to assist land managers in prioritizing allocation of water quality improvement practices, and to quantify relationships between site specific management decisions and resulting water quality. Farm scale assessment and monitoring are critical components of water quality management at the farm level. In developing on-farm assessment and monitoring programs agriculturalists must establish specific monitoring objectives, and establish a framework of sample site location and collection frequency which is synchronous with agricultural discharge patterns through space and time. Farm scale monitoring programs should target the specific pollutants of concern relative to receiving waters (e.g., stream with high nitrogen levels) and on-site agricultural practices which could generate the pollutant of concern (e.g., nitrogen fertilization of a pasture). Opportunities to use water quality monitoring data to quantify relationships between specific agricultural management practices and resulting water quality should be capitalized upon to increase both the site-specific knowledge base and return on financial investment in monitoring.

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What's the Bottom Line? Estimating Costs and Benefits for Central Coast Water Quality Conservation Practices

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Introduction

Water quality protection and maintenance have garnered considerable attention recently in the six counties (San Mateo, Santa Cruz, Santa Clara, San Benito, Monterey and San Luis Obispo) draining to the Monterey Bay National Marine Sanctuary. In particular, Central Coast farmers are facing more scrutiny and regulatory pressures with respect to land management and agricultural runoff. Economic analyses of water quality conservation practices were identified as high priority needs by the Water Quality Protection Program (WQPP) of the Sanctuary, a coalition of 29 public and private coastal agencies, organizations and businesses (WQPP 1999). Farmers frequently cited the high initial cost of installing new conservation practices as a barrier to adoption. However, most farmers had never quantified the maintenance, clean-up, and repair costs of their current runoff management practices.

UC Cooperative Extension (UCCE), in collaboration with the USDA Natural Resources Conservation Service (NRCS), coastal farmers, landowners, and other researchers, agencies and industry representatives conducted research to estimate costs and potential benefits for a series of water quality conservation practices. The goal of the studies was to provide area farmers and agencies providing technical assistance with information to help in making important water quality planning and management decisions. To date, nine economic analyses have been completed (Tourte, et al.).

Study Contents

Each of the nine studies describes a particular conservation practice and provides a budget table estimating costs (costs per unit and reduced returns) and potential benefits (additional returns and reduced costs) for its installation, operation, and maintenance. Costs include such items as seed for planting of ground cover, equipment use, and labor for storm repairs. Benefits include such items as improved returns from minimizing yield losses associated with flood damage. Other benefits include reductions in annual repair costs after the more effective practice is installed. Estimated costs and potential benefits are shown for low, representative, and high cost scenarios. More detailed information on labor and material inputs for the representative scenario is contained in two additional tables. Some practice costs and benefits are calculated on an annual basis (e.g., cover crops, on-farm row arrangement), while others are expanded to reflect a five-year decision-making horizon (e.g., water-sediment control basin, underground outlet). The former conservation practices are generally considered management techniques and the latter structural practices.

Results

Costs and benefits vary depending on such variables as the design and capacity of the practice, the location of the practice site, number of storm events per year, and the 'suite' of accompanying practices. However, costs and potential benefits can be estimated given stated assumptions. For example, using the representative cost and benefit scenario for two different annual management practices, *on-farm row arrangement* has the potential to provide farmers with a net financial savings of $2,580 per 25-acre parcel in each year of use (Table 1). Costs include layout and marking of rows, and charges to prepare land and install a drip irrigation system over and above typical preparation costs. Benefits include yield improvement, thus additional income, from reduced plant loss and improved growing conditions associated with the installation of this practice. Potential long-term benefits, such as a reduction in the loss of productive topsoil, are difficult to quantify or value. No cash savings for such long-term benefits are therefore included in the study. In contrast, the practice *cover crop* has a net cost of $119 per acre associated with its use each year (Table 1). Costs include land preparation, drill seeding the cover crop, irrigation, mowing vegetative growth, and incorporating plant materials into the soil. Benefits include a small reduction in labor and equipment use associated with the prevention and repair of flood control and storm events.

With respect to multi-year structural practices, a non-engineered water-sediment control basin can have a net cost of $3,411 for a 237 cubic yard basin during the first year, with a continued net cost of $1,367 in each of the next four years (Table 2). Costs include site preparation, installation of pipes, couplers and risers, sandbags to channel and check water, and planting ground cover around the perimeter. They also include income lost from taking 0.1 acre out of production to install the basin. Costs can vary substantially depending on the maintenance associated with rainfall amount and number of storm events each year. Benefits include a reduction in labor and equipment use for prevention and repairs associated with flood control and storm events. In contrast, an underground outlet has a net cost of $3,860 for a 400 linear foot unit during the first year, and a net savings of $1,332 in each of the next four years (Table 2). Costs include site preparation, installation of the pipeline and maintenance of the pipeline once installed. Benefits include income improvement from a decrease in plant loss or damage and decreased labor and equipment use from storm events.

Costs for consultants, permits, and other potential specialized charges are not included in the studies, nor are cost-sharing contributions from federal and other local assistance programs that may be available to offset direct expenses borne by farmers adopting these practices. All conservation practices that were studied have the potential to prevent or minimize downstream impacts and/or property damage associated with storm events and agricultural runoff. Additional non-quantified benefits include reduced conflicts with neighbors and exposure to legal and regulatory actions.

Outreach and Extension

Study results have been incorporated into the 15-hour educational curriculum for the joint UCCE-NRCS Farm Water Quality Short Courses. Roughly 650 Central Coast farmers have completed the course to date. The analyses are also used to provide management and decision-making information to coastal farmers, and NRCS and Resource Conservation District (RCD) technical field staff. The studies have also been provided to NRCS District Conservationists to inform the selection of cost share rates for the Environmental Quality Incentives Program (EQIP). Finally, the studies are distributed through local UCCE, NRCS and RCD offices, and are available via the internet at either http://cesantacruz.ucdavis.edu or http://www.agecon.ucdavis.edu/outreach/Outreach.htm.

Acknowledgements
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Table 1. Summary costs and benefits ($/unit) for annual central coast conservation practices – representative scenario*

Practice	Unit	Costs	Benefits	Net Income Change
Cover crop	acre	147	28	-119
On-farm row arrangement	25-acre parcel	920	3,500	2,580
Grassed farm road	5,800 linear feet	310	650	340
Grassed filter strip	.5 acre	234	165	-69

* Full studies can be accessed and downloaded at: http://cesantacruz.ucdavis.edu or http://www.agecon.ucdavis.edu/outreach/Outreach.htm

Table 2. Summary costs and benefits ($/unit) for multi-year central coast conservation practices – representative scenario*

Practice	Unit		Year 1	Years 2-5
Critical area planting	acre	Costs	903	121
		Benefits	0	**
		Net Income Change	-903	-121
Grassed waterway	1,000 linear feet	Costs	980	329
		Benefits	0	275
		Net Income Change	-705	-54
Hedgerow planting	1,000 linear feet	Costs	2,918	515
		Benefits	0	**
		Net Income Change	-2,918	-515
Underground outlet	400 linear feet	Costs	5,918	726
		Benefits	2,058	2,058
		Net Income Change	-3,860	1,332
Water-sediment control basin	237 cubic yards	Costs	4,061	2,017
		Benefits	650	650
		Net Income Change	-3,411	-1,367

* Full studies can be accessed and downloaded at: http://cesantacruz.ucdavis.edu or http://www.agecon.ucdavis.edu/outreach/Outreach.htm
** No benefits assumed for this study, but may apply in some situations.

Decision-Making Tools for Pest Management—Additions to the UC IPM Pest Management Guidelines

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Introduction

UC IPM staff are working with UC IPM Pest Management Guideline (PMG) authors and the USDA Natural Resources Conservation Service (NRCS) to enhance the PMGs. New features are year-round IPM programs that organize pest management activities, and toxicity information to help farmers in selecting pesticides when they are needed. Year-round IPM programs identify the major activities farmers need to be doing at each crop growing/development period to implement a comprehensive IPM program. These new programs are available on the UC IPM Web site for prunes, almonds, and cotton, and will be completed for many crops, including plums, grapes, alfalfa, strawberries, avocados, peaches, and nectarines over the next year. Recently added "compare treatment" buttons on each PMG link to graphical displays that make it easy to compare the potential of leaching and runoff for each pesticide recommended in the PMG. This information is currently available on 11 crops, but links will be added to all PMG crops in Winter 2004.

UC IPM Pest Management Guidelines

The UC IPM Program developed the Pest Management Guidelines to provide practical information on pest management techniques for controlling a broad range of California pests. Authored by UC ANR scientists, the PMGs provide University of California's official recommendations for managing pests in agriculture, floriculture, and turfgrass, including 43 different crops or crop groups. PMGs contain the best science-based information available to the authors and are intended to help farmers implement environmentally sound pest management programs. The PMGs are updated regularly and peer-reviewed.

For each important pest of a crop, and many minor or occasional pests, PMGs help farmers identify pests using illustrated descriptions of the pests and their damage, or plant symptoms, and select management tactics from available cultural, biological, and pesticide controls.

The PMGs are organized by pest, which often is not the most useful way to think about pest management, since a farmer often needs to take actions that affect more than one pest at a time. When presented with individual-pest information only, a farmer has to figure out what actions need to be taken when. But a recent effort has added an integrated view of managing pests in crops that organizes the various activities seasonally and adds new information related to water quality.

Year-Round IPM Plans

Working with authors of the PMGs, IPM staff members have been developing year-round IPM plans that identify the major activities farmers need to do at each crop growing period to implement a comprehensive IPM program. Developed for specific crops, annual IPM program checklists (figure 1) guide farmers through a year of monitoring pests, making management decisions, and planning for the following season.

Done?	Early squaring period activities
	• Begin weekly monitoring of plant growth. • Continue tracking degree-day accumulations for plant growth.
	Monitor for armyworms, cabbage loopers: • Treat** if needed according to PMG
	Monitor for spider mites, aphids, and whitefly: • Keep records on the monitoring form • Treat** if needed according to PMGs
	Begin sweep net sampling and square retention monitoring for lygus activity: • Keep records on the monitoring form. • Treat** if needed according to PMG.
	Survey and manage weeds: • Complete the weed survey form. • Treat** if needed according to PMG.
	Sample for both races of *Fusarium* if there is evidence of *Fusarium* in the field or if you want to plant a variety with unknown resistance.
	Manage alfalfa next to cotton.
	Adjust nitrogen to prevent rank growth.

Figure 1. Sample seasonal (early squaring period) checklist from the year-round IPM program for cotton.

On the Web, the year-round IPM programs link to:

- detailed monitoring instructions that include decision thresholds;
- monitoring forms to print and use to keep records;
- photo pages to help farmers identify the pest problems, as well as beneficial insects, that they see while monitoring;
- pesticide application checklist to help identify ways to prevent or mitigate negative impacts of pesticide treatments; and
- pest management guidelines to determine management alternatives

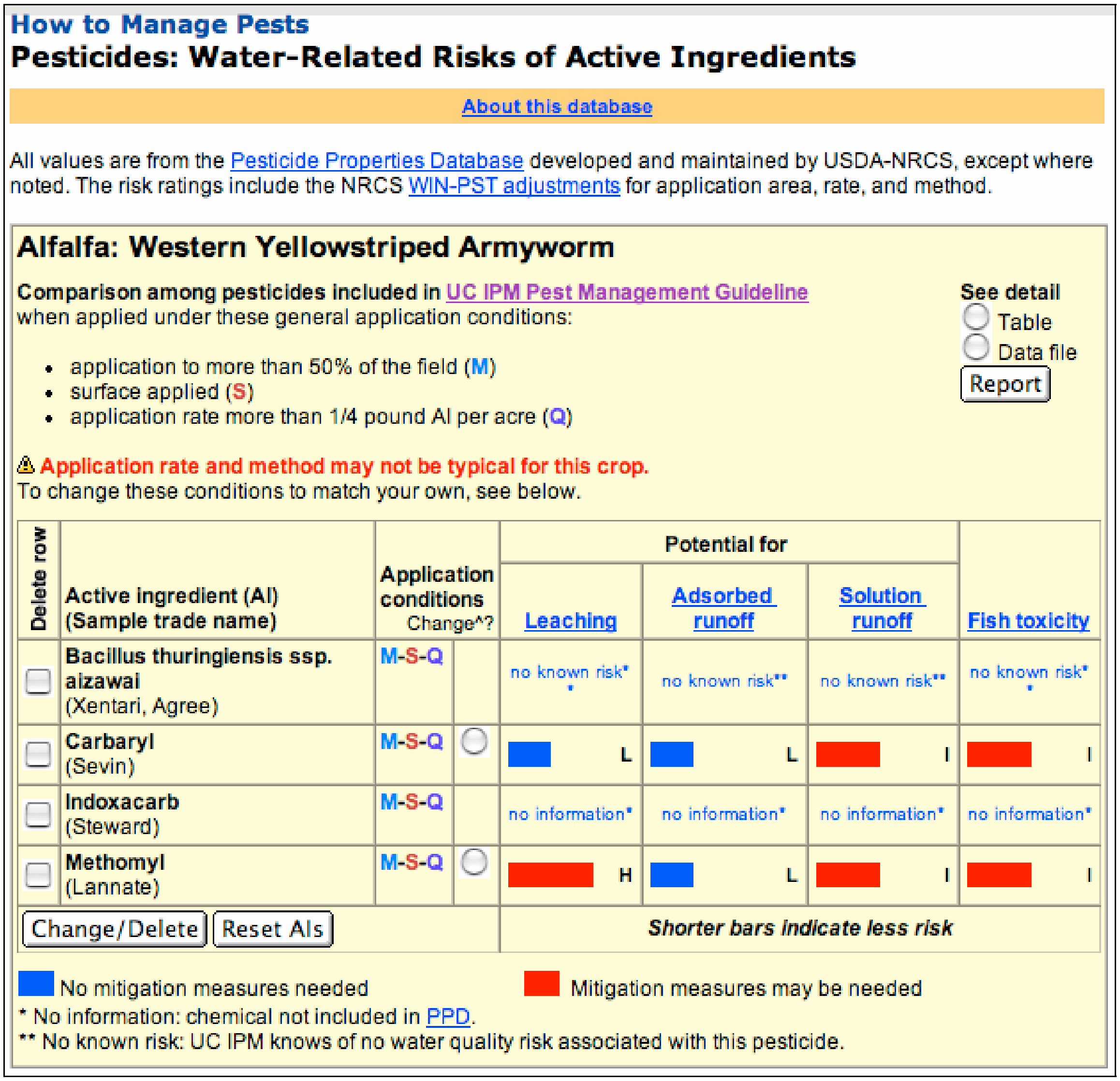
This new resource can help a farmer take the right action at the right time and collect information that can help in planning for the next growing season. They help a farmer know when and how to monitor, correctly identify the pest problem, and analyze the options available after determining that control is needed.

Year-round IPM programs are available under "How to Manage Pests: Agriculture" on the UC IPM Web site (http://www.ipm.ucdavis.edu/) for prunes, almonds, and cotton. Year-round programs will be completed for many crops, including plums, grapes, alfalfa, strawberries, avocados, peaches, and nectarines over the next year.

Pesticide Selection Using New Water Quality Impacts Database

Until recently, if a farmer decided to apply a pesticide treatment to control a pest, the PMGs had limited information to help assess possible impacts on water quality. To fill that gap, in Fall 2004, UC IPM added a new database and decision tool, called WaterTox. Using information from USDA–Natural Resources Conservation Service (NRCS), the tool evaluates potential for pesticides to move with water and eroded soil or organic matter, and to affect nontarget organisms. Its purpose is to help farmers consider risk of leaching and runoff in making pest management decisions, particularly pesticide choice.

To each PMG for a specific crop and pest, UC IPM added a Water Quality—Compare Treatments button. Located within the tables that show possible treatments, especially pesticides, the button links to a graphic display that compares relative risk of leaching and runoff among the listed pesticides. Using this comparison of potential to move off site and affect nontarget organisms, farmers can make more informed choices when selecting among pesticides recommended in the PMGs.



How to Manage Pests

Pesticides: Water-Related Risks of Active Ingredients

About this database

All values are from the Pesticide Properties Database developed and maintained by USDA-NRCS, except where noted. The risk ratings include the NRCS WIN-PST adjustments for application area, rate, and method.

Alfalfa: Western Yellowstriped Armyworm

Comparison among pesticides included in UC IPM Pest Management Guideline
when applied under these general application conditions:

- application to more than 50% of the field (M)
- surface applied (S)
- application rate more than 1/4 pound AI per acre (Q)

See detail
Table
Data file
Report

⚠ Application rate and method may not be typical for this crop.
To change these conditions to match your own, see below.

Delete row	Active ingredient (AI) (Sample trade name)	Application conditions	Change^?	Potential for: Leaching	Potential for: Adsorbed runoff	Potential for: Solution runoff	Fish toxicity
	Bacillus thuringiensis ssp. aizawai (Xentari, Agree)	M-S-Q		no known risk**	no known risk**	no known risk**	no known risk**
	Carbaryl (Sevin)	M-S-Q		L	L	I	I
	Indoxacarb (Steward)	M-S-Q		no information*	no information*	no information*	no information*
	Methomyl (Lannate)	M-S-Q		H	L	I	I

Change/Delete Reset AIs

Shorter bars indicate less risk

No mitigation measures needed   Mitigation measures may be needed

* No information: chemical not included in PPD.

** No known risk: UC IPM knows of no water quality risk associated with this pesticide.

Figure 2. Sample risk comparison table from WaterTox.

The risk comparison table (figure 2) lists each pesticide active ingredient included in the PMG, usually with a sample trade name to help the user identify the pesticide. Shown in the table are long-term toxicity to fish and potentials for leaching, adsorbed runoff, and solution runoff.

- Potential for leaching indicates the tendency of a pesticide to move in solution with water and leach below the root zone.
- Potential for adsorbed runoff is the tendency of a pesticide to move in surface runoff attached to soil particles.
- Potential for solution runoff indicates the tendency of a pesticide to move in surface runoff in the solution phase.
- Fish toxicity is the long-term toxicity level for fish, for pesticide in solution.

Ratings and values in the chart. Data values in the chart come primarily from the USDA-NRCS Windows Pesticide Screening Tool (WIN-PST) (http://www.wcc.nrcs.usda.gov/pestmgt/winpst.html). Values are shown as bars. Bars vary in length based on low, intermediate, or high potential for off-site movement; shorter bars indicate less risk. A letter abbreviation (V=very low, L=low, I=intermediate,

H=high, X=extra high) appears next to each bar.
If the pesticide listed in the PMG is included in the WIN-PST database, WIN-PST's risk values are used. If a pesticide is not included in WIN-PST, and the chemical poses no known risks to water quality, the table indicates "no known risk." In all other cases where a chemical is not included in the WIN-PST database, risks are labeled "no information."

Change application conditions. The potential risk of leaching and runoff may be affected by the amount of pesticide used, the area covered, and how much pesticide comes in contact with the soil. WaterTox takes a user's input about these factors to adjust the risk ratings given by the program.
The initial data in the table are computed for these standard application conditions: application to more than 50% of the field (M); surface application (S); and standard application rate of more than 1/4 pound active ingredient per acre (Q) (except for pyrethroids, which are always used at low rates). Since a user's rate and method may not be the same as these standard conditions, and how one applies the pesticide can impact the risks to water quality, the program allows users to specify how much area is being treated, how much pesticide will come in contact with the soil, and the actual application rate.

What area is being treated? Will the pesticide be applied to more than 50% of the field, or will less than 50% of the field be treated, by using strip applications or spot sprays, for instance?

How much pesticide will come in contact with the soil? Surface applied means that the pesticide will be applied to bare ground or an incomplete canopy. Foliar applied means that the pesticide will be applied when the crop or weeds are at nearly full canopy. Dormant sprays are not "foliar applied." Soil incorporated means that the pesticide will be incorporated into the soil.

What is the application rate? Rates above 1/4 pound of active ingredient per acre are considered the "standard" rate. Rates from 1/10 to 1/4 pound active ingredient per acre are considered to be low by WIN-PST. Rates less than 1/10 pound of active ingredient per acre are considered to be ultra low by WIN-PST.

Eventually, a calculator will be included to help users determine the rate of active ingredient in pounds per acre.

Source of the Data and Algorithms in WaterTox

WaterTox is a partial implementation of the Windows Pesticide Screening Tool (WIN-PST) developed by USDA-NRCS. All data come from their Pesticide Properties Database (http://www.wcc.nrcs.usda.gov/pestmgt/winpst.html). The program includes WIN-PST's rating adjustments for application area, rate, and method. Unlike WIN-PST, the first (2004) version of WaterTox does not provide information for specific soils or allow a user to consider impact of water table depth, irrigation, residue management, or other site conditions. A version of WaterTox to be released early in 2005 accounts for soils that have high loss potential and incorporates the pesticide's long-term toxicity to fish and humans into the pesticide loss rating.

Session II

Technology to Address Air Quality Issues

Session Chairs:

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Current Issues Related to Agriculture and Air Quality in the San Joaquin Valley

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Introduction

California's San Joaquin Valley, which contains millions of acres of productive farmland, faces serious air quality problems. Over the past three decades, significant reductions in emissions from a wide variety of sources, including some agricultural sources, have resulted in clear improvements in San Joaquin Valley air quality. In spite of these efforts, however, the Valley air still does not meet state and federal health-based air quality standards. In order to meet these important standards as required under state and federal law, and to protect public health, the San Joaquin Valley Air Pollution Control District has developed and adopted new air quality attainment plans that include additional control measures aimed at reducing emissions from an even broader range of sources, including more agricultural sources of air pollution.

This paper addresses current air quality issues associated with agriculture in the San Joaquin Valley. It specifically describes the contribution of agricultural sources of air pollution to San Joaquin Valley air quality problems, the legal and regulatory framework for agricultural air pollution control, examples of control measures that Valley farmers are implementing to reduce air emissions from their operations, and some of the current agricultural research efforts, supported by government agencies and agricultural industries, that are leading to cost effective solutions to air pollution problems.

Air Emissions from Agricultural Operations

The San Joaquin Valley Air Basin is designated as an extreme non-attainment area for the federal one-hour ozone standard and a serious non-attainment area for the federal particulate matter (PM10) standard. The air pollutants of concern in addressing compliance with the ozone standard include volatile organic compounds and oxides of nitrogen, which combine in the atmosphere to form ozone (photochemical smog). The pollutants of concern for the PM10 standard include: particulate matter that is directly emitted into the atmosphere, such as dust and soot; as well as other chemicals, such as ammonia and sulfur dioxide, that are released into the air and may subsequently form PM10.

Agricultural sources of air pollution include on-field activities, such as tilling and harvesting, internal combustion engines, the burning of agricultural wastes, pesticide and fertilizer application, and livestock waste storage and handling operations. The San Joaquin Valley Air Pollution Control District and the California Air Resources Board routinely estimate emissions from these and other source categories based on emission factors developed through research and testing, and activity levels reported by industry. Table I below summarizes the annual average emissions of particulate matter (PM10), volatile organic compounds, and oxides of nitrogen from farming operations as estimated by the California Air Resources Board for the year 2003.

The total estimated annual average emissions rate shown in Table I for PM10 from agricultural operations for 2003, 160.1 tons/day, represents approximately 46% of the total of all PM10 emissions in the San Joaquin Valley. It should be noted that Table I does not include ammonia emitted from agricultural operations, which may combine in the atmosphere with other air contaminants to form additional quantities of PM10.

Table I – Emissions from Agricultural Operations in the San Joaquin Valley for 2003

	Particulate Matter (PM10), tons/day	Volatile Organic Compounds, tons/day	Oxides of Nitrogen, tons/day
Tilling Dust	35.9	-	-
Harvesting Dust	36.4	-	-
Windblown Farm Dust	47.7	-	-
Waste Burning	9.9	8.5	4.0
Confined Animals - Dust	7.0	-	-
Livestock Waste – Dairy	-	36.0	-
Livestock Waste – Beef	-	12.2	-
Livestock Waste – Poultry	-	12.5	-
Livestock Waste – Other	-	1.4	-
Unpaved Farm Roads	10.8	-	-
Unpaved Equipment Areas	7.2	-	-
Mobile Farm Equipment	4.0	8.6	59.5
Irrigation Pump Engines	1.2	2.4	18.0
Pesticides and Fertilizer		25.7	
AGRICULTURAL EMISSIONS TOTAL	160.1	107.3	81.5

The total estimated agricultural emissions rate shown in Table I for volatile organic compounds, 107.3 tons/day, represents approximately 27% of all estimated VOC emissions for the Valley. For oxides of nitrogen, the estimated agricultural emissions rate of 81.5 tons/day represents approximately 16% of total emissions in the Valley.

Current Legal and Regulatory Framework for Addressing Emissions from Agriculture

Under federal law, because the San Joaquin Valley is designated as a non-attainment area for federal air quality standards, the Valley Air District is required to develop and implement attainment plans that include control measures and technologies aimed at reducing emissions from all significant sources of air pollution, including agricultural sources. The requirements of California state law with regards to agricultural air pollution control, as described by CAPCOA, are more specific. Under Senate Bill 700 (Florez), adopted in September of 2003, the Valley Air District is required to:

- Adopt and implement rules requiring best available control measures (BACM) and best available retrofit control technology (BARCT) for farm activities including tilling, harvesting, and the raising of animals by January 1, 2006.
- Adopt and implement rules requiring best available retrofit control technology (BARCT) for stationary and portable engines (e.g. irrigation pump engines) used in agriculture. In developing these rules state law requires that requirements be similar to those in place for nonagricultural sources, and that engine size, use, and the degree and cost effectiveness of control be considered.
- Issue permits to larger agricultural sources of air pollution. SB700 removed a longstanding permit exemption in State law for equipment used to grow crops or raise animals.
- Adopt and implement a permit rule by July 1, 2006 requiring operators of large confined animal facilities, such as dairies and poultry ranches, to mitigate emissions, including volatile organic compound and ammonia emissions, to the extent feasible.

Control Measures to Reduce Emissions

District Rule 4550 (Conservation Management Practice Plans) was adopted in May of 2004 to address state and federal requirements and reduce dust emissions from on-field farming activities. Rule

4550 requires farmers cultivating over 100 contiguous acres, and operators of larger confined animal facilities, to submit Conservation Management Practice Plans to the District by December 31, 2004. Unlike air pollution control rules affecting many other industries, Rule 4550 does not prescribe specific air pollution controls for farms. Instead, it allows farmers to create their own Conservation Management Practice Plans, by choosing five dust control measures from a list of over 80 approved practices created during the rule development process, with measures proposed by farmers, and input from representatives of the agricultural industry, the USDA Natural Resources Conservation Services, and California Regional Conservation Districts. Once approved, the Conservation Management Practice Plans will also be used by the District to quantify the Valley-wide PM10 reductions that farmers are achieving with these practices.

Examples of approved dust control measures for land preparation and cultivation include conservation tillage, which reduces the number of tractor passes across fields; chemigation and fertigation, which eliminate the need to travel through fields to apply chemicals; cover crops, which may reduce wind erosion; and combined operations, which result in less land disturbance. Many of these measures may reduce operating costs as well as dust emissions.

For harvesting operations, approved dust control measures include equipment changes that reduce passes through fields; night harvesting, which reduces PM10 emissions because harvest occurs when humidity is higher and the air is more calm; pre-harvest soil preparation with water or stabilizing materials; and combined operations, which result in less soil disturbance.

Examples of other approved practices include: integrated pest management, which may minimize the need for application of chemicals; the use of cleaner irrigation power units, which significantly reduces nitrogen oxide emissions as well as PM10 emissions; grinding, chipping and shredding of prunings and downed trees, as opposed to open burning of these materials; and conservation irrigation, which may reduce weed populations and the resulting need for tillage.

In addition to reducing PM10 emissions from on-field activities, District Rule 4550 also requires that practices be implemented to reduce emissions from unpaved farm roads and equipment storage areas. For unpaved roads and equipment areas, approved dust control practices include: paving; watering; the application of dust suppressants including road oils, organic materials, polymers, and hydroscopic materials; the use of gravel; posting of speed limits; and the creation of wind barriers.

In order to implement the requirement for Best Available Retrofit Control Technology on stationary farm engines, including those used to drive irrigation pumps, the District is developing amendments to District Rule 4702 (Internal Combustion Engines). The amended rule would establish new emissions limits for compression ignition and spark ignited engines and would be implemented over a period of several years.

The District will also be developing a rule to reduce volatile organic compound and ammonia emissions from large confined animal facilities by July 1, 2006, as required by state law. The first step in the development of these requirements is for the Californian Air Resources Board to establish a definition for the term “large confined animal facility” that can be used to identify facilities requiring control. During 2004, the State Board held public workshops throughout California to obtain input on this definition. Once that definition is established, the District will proceed with the development of the emissions control rule.

Ongoing Research

The development of effective air pollution control strategies requires a fundamental understanding of emitting processes and the mechanisms of air pollutant formation that can only be obtained through scientific research. Organizations funding current agricultural air pollution research in California include the U.S.D.A, the U.S. EPA, the California Air Resources Board, California air districts, agricultural industry groups, and academic foundations. Research is being conducted by major universities including the University of California, California State Universities, and Texas A&M; as well as by consultants and independent contractors working under the direction of the U.S. EPA, the

California Air Resources Board, the California Department of Food and Agriculture, and California air districts. Much of the current research is aimed at obtaining a better understanding of emissions of volatile organic compounds and ammonia from confined animal facilities. The California Air Resources Board web site at www.arb.ca.gov/ag/research/research.pdf includes a list of some of these important projects.

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Agricultural Air Quality Update – 2005: Have We Turned the Corner?

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Introduction
Beginning in the mid-1990's and into the new century, air quality has risen to the forefront of issues facing California agriculture. From agricultural burning of crop residue to controlling fugitive dust, from replacing old irrigation pump engines to decrease emissions of oxides of nitrogen (NOx) to lowering pesticide emissions of volatile organic compounds (VOCs), the 21st century farmer has truly begun to feel the impact of the air quality issue. However, there is light at the end of this long tunnel, and while we are not there yet, agriculture may finally see the time where air quality issues are no longer the leading issue discussed at the local coffee shop.

The Issues
In the early 1990's, agriculture was immersed in the issues of reducing agricultural burning, utilizing new low sulfur diesel fuel, and beginning of the discussion surrounding the fugitive dust rules to reduce dust on farms. Initially, farms with forage crop residue and prunings were forced to burn only on certain days, obtain burn permits and pay fees. Many times, several days would go by without any burning, which would lead to a day when the entire valley would light up, inundating the valley with smoke and making agriculture stand out like a sore thumb. This approach has given way to a system known as the smoke management program, where agriculture is granted a certain amount of burning on each day, but the amount is dictated by the given day and the regional location. In 1994, the use of low-sulfur diesel fuel became the norm for use in tractors and diesel-fired irrigation pump engines. Of course, this has come at the expense of increased cost, especially compared to other states and growing regions. By far, the biggest issue of the nineties was the battle over fugitive dust and the impact on farms. The final rules are drastically different than many of the early proposals that floated around in the beginning of the debate, such as water sprays on discs and "no-till days". However, the fugitive dust rules, known as Regulation VIII, did set forth some ground-breaking rules on agriculture by mandating the application of water or dust suppressants on unpaved roads during periods of high activities.

At the start of the new century, environmental activism and the passage of the infamous SB 700 series legislation has brought about far reaching government intervention in the form of air pollution permits, conservation management practice (CMP) plans, fees, and actual farm inspections. With the San Joaquin Valley in non-attainment for PM10, increased scrutiny came forward in the form of rules governing "on-field" agriculture. The Conservation Management Practice (CMP) rule was passed, which required farms in excess of 100 acres to implement five (5) CMPs per crop, one each for unpaved roads and unpaved equipment yards, and then one each for land preparation and cultivation, harvesting and then one in the "other" category. The "other" category covers things such as windblown dust, pesticides, or burning. In addition to these fugitive dust (PM10) requirements, local air pollution permits were required for fuel-fired engines where emissions exceeded 12.5 tons per year of NOx. Federal Title V permits were required for farms in excess of 25 tons per year of NOx. Besides the permits, the local air district has now begun looking at cleaning up those fuel-fired engines. The first draft of that attempt has been released, and all existing engines would have to be replaced. The oldest engines would have a maximum of four years to be replaced and newer engines, installed after 1996 would have ten years since the date of original installation to be replaced. Details continue to be discussed and debated on this draft rule with the final rule to be adopted sometime in mid-2005.

In the very near future, farms will face unprecedented scrutiny. Forklifts and tractors, pesticides, gasoline storage tanks, the elimination of agricultural burning, another lower emission diesel fuel, and confined animal feeding operations (CAFOs) are all on the short list of issues agriculture will address in this first decade of the new millennium. The California Air Resources Board (CARB) is looking at replacing existing in-use forklifts with either electric or low-emission forklifts over a three to four year period. Aboveground storage tanks will be required to install vapor recovery systems on each tank, which have been estimated to cost as much as $18,000 per tank. The California Department of Pesticide Regulation (DPR) is currently developing a regulation to lower VOC emissions from pesticides statewide.   Potential options include, reformulation, low emission application techniques, limitations on spraying days, among others. Another new low emission diesel fuel is on the way. Beginning in 2006, ultra-low sulfur will become available in California, with the rest of the nation using the fuel in 2007.

Conclusion
Air quality has become a fixture in the agricultural landscape. Agronomic practices, new farm equipment and the products we apply all will soon have some element that address clean air. The impact is far reaching and certainly costly. But our own efforts are starting to pay dividends. The formation of the Air Coalition Team (ACT), the solid results of agriculture's voluntary efforts, and finally the decision by agriculture to finally stand up to the onslaught of regulatory pressures are all examples that demonstrate the tide is finally beginning to turn. Much of this is due to the outcome of recent scientific research in the form of actual on-field measurements of emissions from farming operations, which has identified the most critical areas where we should focus our clean air efforts and where we shouldn't waste our time. The lawsuits aren't as successful, and the regulatory proposals are not as hair-brained. While we are being inundated at the current time, the landscape appears to be changing with emphasis switching to homeowners, which is exactly where it should be.

Air Quality Issues and Policy in Animal Agriculture

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Introduction

Federal, state, and regional air quality regulators consider parts of California (San Joaquin Valley and South Coast) as having the nation's worst air quality with regard to ozone[3] and particulate matter[4] (PM_{10} and $PM_{2.5}$), and newspapers convey this picture nationwide (e.g., "California has the USA's worst air quality"; USA Today). Until 2004, California agriculture was exempt from air quality regulation. Environmental groups successfully challenged this exemption in court, which resulted in a legal settlement and the introduction of new legislation (SB 700). From January of 2005 on, dairies in the San Joaquin Valley are mandated to develop Conservation Management Plans (CMPs) to reduce fugitive dust (Particulate Matter, PM10) and in some cases to apply for air permits. Unfortunately, we are in a situation in which dairies are being regulated based on very limited data related to their emission potential and effective control techniques and technologies have yet to be studied.

It is widely accepted that dairies emit ammonia, particulate matter, volatile organic compounds (VOC), hydrogen sulfide, odors, and certain "greenhouse gases" (GHG) like methane and nitrous oxide. The main air quality issue currently under discussion in California is how dairies contribute to ozone and particulate matter emissions and how these emissions can be reduced. Research efforts are underway at UC Davis and CSU Fresno to address these issues and to improve the knowledge base regarding dairy air quality.

Do cows rival cars as smog producers?

VOCs are problematic because they form ozone (smog). VOCs from dairies occur during anaerobic decomposition of cattle manure. Preliminary estimates by the California Air Resources Board (ARB) and regional air district agencies (SJVAPCD) indicate that dairy operations are significant contributors to VOC emissions and that cows will overtake cars as VOC producers in the near future. Current claims are that a 700 head dairy emits the same amount of VOC as 60,000 cars. These claims, however, are not based on scientific studies of VOC on dairies but on methane (which is not a VOC) data from a climate chamber study conducted in 1938. Lack of recent and more accurate scientific VOC data has forced regulatory agencies, under public pressure to address this issue, to use the calculations of the 1938 study. However, the use of this VOC emission factor in California triggered EPA to contract with the National Academy of Science (NAS) to revisit and re-examine the scientific merit and use of emission factors from animal feeding operations. The final NAS report stated that the use of emission factors for AFO's is inappropriate and should be replaced by more site specific (process-based) approaches. State and regional air quality regulatory agencies are currently reviewing VOC emission estimates from dairies also using data from three ongoing studies on VOC emissions from dairies: one at commercial dairies conducted by CSU Fresno, one by a consultant company at a commercial dairy, and a third study at UC Davis under controlled conditions. These ongoing studies will help determining if in fact cows rival cars as smog producers.

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[3] Ozone is a pollutant formed by chemical reactions involving nitrogen oxides, reactive organic gases, and sunlight. Ozone is a powerful respiratory irritant that can cause coughing, shortness of breath, and headaches.

[4] Particulate matter (PM) is defined as dust particles suspended in the air. For health reasons, the most relevant PM emissions are inhalant particulate matter less than 10 microns in diameter (PM10) and the fine particulate matter less than 2.5 microns (PM2.5) in diameter, which can lodge in the deepest, most sensitive areas of the lung and cause respiratory and other health problems.

Other pollutants
In addition to VOCs, dairies emit primary and secondary particulate matter. Primary particulate matter comes from dirt-floored surfaces within the dairy, including either roads or drylot corrals. Dairy operations also emit substantial amounts of ammonia, which is a precursor in the formation of secondary particulate matter (e.g., ammonium nitrate). Ammonia is mainly formed by hydrolysis of urea (from urine) in the cow holding-pens and during field application of "waste material". Once ammonia is formed, it can volatilize into the atmosphere. Secondary particulate matter can form through chemical reaction of ammonia with combustion gases (NOx and SOx). Current emission factors for ammonia and particulate matter for dairy operations were derived from very limited measurements on one or two dairies.

Dairy air emission mitigation
The most pressing question with regard to air quality for the dairy producer is how emissions from the dairy can be reduced. To address this question, an air quality research and extension program was developed in the Animal Science Department at UC Davis. As part of this program, an air quality research facility was constructed on campus and is fully operational to study air emissions reduction strategies from cows, heifers, and their manure using scientific methods and proper experimental design. One of the main avenues to reduce unwanted losses of nutrients is through nutritional manipulation. The objective of nutritional studies is to optimize the animal's nutrient efficiency and thereby reduce unwanted emissions. Recent research conducted in our lab on effects of diet on ammonia and volatile fatty acid volatilization showed that significant emission reductions can be achieved without negatively affecting performance of cows.

Particulate matter emissions are typically not associated with manure management facilities (e.g., lagoons) or concrete- floored housing facilities (e.g., freestalls). Freestall and drylot corral housing differ significantly in their particulate matter emission potential. Manure from freestalls is flushed several times daily, resulting in freestall air emissions that are relatively insignificant and therefore, no air emission mitigation techniques or technologies for freestall conditions (besides feeding strategies for cows) are commercially available or deemed necessary. Manure in drylot pens accumulates over time. When the top layer of the manure pack dries out, cow activity leads to primary particulate matter emissions, which means that pulverized animal manure and soil particles are kicked up by cows' hoof action. Most effective particulate matter mitigation research should therefore focus on drylot corral management in dairies. Drylot pens are also believed to be the major source for ammonia volatilization.

Another main source for gaseous emissions on a dairy is its manure storage facilities. Manure storage and management affects the physical, chemical, and biological properties of manure nutrients and consequently impacts air emissions. Once excreted, manure undergoes aerobic or anaerobic decomposition processes that generate different air emission profiles. Some of the emission mitigation candidates that are most often discussed as promising manure handling and treatment technologies to reduce air emissions are manure storage covers, anaerobic digesters, aerators, solid separators, compost, and pH control of stored manure. Several of these technologies have been studied in descriptive studies, but side by side comparisons currently take place under controlled and replicated conditions to quantify the mitigation effects scientifically.
The dairy air quality research in the Animal Science Department at UC Davis focuses on:

1. nutritional management (test cow diets with respect to nutrient excretion),
2. environmental management (water sprinkling of drylot pens, provision of shade, bedding, frequent manure harvest from corrals, chemical additives, stocking rates etc.),
3. manure management (manure storage covers, anaerobic digesters, aerators, solid separators, compost, and pH control of stored manure).

Simultaneous with the mitigation research that is conducted at UC Davis until 2006, an air quality curriculum was developed as part of the California Dairy Quality Assurance Program (CDQAP) to educate producers and regulators on issues related to dairy air quality. This curriculum was presented to more than 800 dairymen in 21 workshops throughout the San Joaquin Valley to achieve "compliance through education".

Particulate Matter Sampler Errors Due to the Interaction of Particle Size and Sampler Performance Characteristics

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This paper is a summary of the work done by Dr. Michael Buser. The complete papers are available online through ASAE.

Introduction

The National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) in terms of PM_{10} and $PM_{2.5}$, are the concentration limits set by EPA that should not be exceeded (U. S. Environmental Protection Agency, 2000a). Further, some State Air Pollution Regulatory Agencies (SAPRA's) utilize the NAAQS to regulate criteria pollutants emitted by industries by applying the NAAQS as property line concentration limits. The regional or area consequences for multiple exceedances of the NAAQS are having an area designated as non-attainment with a corresponding reduction in the permit allowable emission rates for all sources of PM in the area. The source-specific consequence of an exceedance of the NAAQS at the property line is the SAPRA denying an operating permit. The current PM_{10} primary 24-hour NAAQS is 150 micrograms per actual cubic meter (µg/acm) (U. S. Environmental Protection Agency, 2000a). The proposed $PM_{2.5}$ primary 24-hour NAAQS is 65 micrograms per actual cubic meter (µg/acm) (U. S. Environmental Protection Agency, 2000a). The secondary NAAQS for PM_{10} and $PM_{2.5}$ are set at the same levels as the corresponding primary NAAQS.

In the initial manuscript in this series of manuscripts entitled "Particulate Matter Sampler Errors Due to the Interaction of Particle Size and Sampler Performance Characteristics: Background and Theory" the evolution of the PM_{10} and $PM_{2.5}$ regulations was briefly discussed. Prior to and since the inclusion of the PM_{10} standard and prior to and since the proposal of the $PM_{2.5}$ standard into EPA's regulation guidelines, numerous journal articles and technical references have been written to discuss the epidemiological effects, trends, regulation, methods of determining PM_{10} and $PM_{2.5}$, etc. A common trend among many of these publications is the use of samplers to collect information on PM_{10} and $PM_{2.5}$. The data collected from these samplers are commonly used in statistical correlations and statistical comparisons to draw conclusions about PM_{10} and $PM_{2.5}$ emission concentrations. All too often, the sampler data are assumed to be accurate measures of PM_{10} and $PM_{2.5}$. The fact is that issues such as sampler uncertainties, environmental conditions (dry standard versus actual conditions), and material characteristics for which the sampler is measuring must be incorporated for accurate sampler measurements. The focus of this manuscript is on the particle size distribution (PSD) characteristics of the material in the air that is being sampled, sampler performance characteristics, the interaction between these two characteristics for PM_{10} and $PM_{2.5}$ ambient air samplers, and the effect of these interactions on the regulatory process.

Sampler Performance Characteristics

A sampler's performance is generally described by either a cumulative collection or penetration efficiency curve. The "sharpness of cut" of the sampler pre-separator or the "sharpness of the slope" of the sampler penetration efficiency curve significantly impacts the accuracy of sampler measurements. Three terms are often used to describe the sharpness of the penetration curve and are frequently and inappropriately interchanged. These terms are ideal, true, and sampler cut. An ideal cut corresponds to the penetration data provided in 40CFR53 (U. S. Environmental Protection Agency, 2000b). A true cut can be described as a step function; all the particles less than or equal to the size of interest are captured on the filter and all particles greater than the particle size of interest are captured by the pre-separator. A sampler cut refers to the actual penetration curve associated with a particular sampler. A sampler cut is defined by a sampler's performance characteristics and based on these characteristics, a portion of the PM less than the size of interest will not be collected on the filter and a portion of the PM greater than the size of interest will be collected on the filter. A common perception is that PM_{10} ($PM_{2.5}$) measurement concentrations are true concentrations and that the concentrations relate to PM with particle sizes less than 10 μm (2.5 μm) or true PM_{10} ($PM_{2.5}$); however, these measurement concentrations are actually based on a sampler cut.

A sampler's pre-separator collection efficiency curve is most commonly represented by a lognormal distribution, characterized by a d_{50} (also referred to as cut-point) and slope of the collection efficiency curve Hinds (1998). The cut-point is the particle size where 50% of the PM is captured by the pre-separator and 50% of the PM penetrates to the filter. The slope is the ratio of the particle sizes corresponding to cumulative collection efficiencies of 84.1% and 50% ($d_{84.1}/d_{50}$), 50% and 15.9% ($d_{50}/d_{15.9}$), or the square root of 84.1% and 15.9% ($\sqrt{d_{84.1}/_{15.9}}$) Hinds (1998). Collection efficiency curves are usually assumed as constant and independent of particle size; in other words, it is assumed that a significant loading of large particles does not affect the pre-separators collection efficiency for smaller particles. Therefore, concentration data used to generate a sampler's pre-separator collection efficiency curve is typically determined by conducting an array of tests over several monodisperse particle sizes using known ambient concentrations. The concentration data from each test is used to determine the collection efficiency, ε_m, associated with each particle size, using the following equation (U.S. Environmental Protection Agency, 2000b).

$$\varepsilon_m = \frac{C_{Pre-Separator}}{C_{ambient}} \quad (1)$$

In equation 1, $C_{Pre\text{-}Separator}$ is the concentration of particles captured by the pre-separator and $C_{ambient}$ is the concentration of particles used for the test. A smooth lognormal curve is fit to the calculated pre-separator collection efficiencies and the sampler performance characteristics (d_{50} and slope) are determined from the fitted curve (U.S. Environmental Protection Agency, 2000b).

There are numerous equation that define and relate theoretical sampler collection and penetration curves under various slope considerations. These equations are defined in Hinds (1998) and Seinfeld and Pandis (1997).

Methods and Procedures

The issue of which sampler performance characteristics are correct is a valid concern; however, the most important question is "what is the intent of the PM regulations". It was previously established that the primary purpose of the regulations is to protect public health. It is quite clear in the literature that PM collected from a PM_{10} sampler should mimic the fraction of PM that penetrates the thoracic region of the human respiratory system, which leads to the perception that the sampler must have a slope greater than 1 based on information presented in the initial manuscript in this series. On the other hand, according to the literature it was EPA's intent for the $PM_{2.5}$ sampler to be a true measure of PM with a particle diameter less than or equal to 2.5 μm AED. An assumption made in the PM_{10} ($PM_{2.5}$) regulations is that it pertains to a measure of particles with an AED less than or equal to a nominal 10 (2.5) μm. The term nominal implies that the measured PM does not account for all mass associated with particles less than or equal to 10 (2.5) μm and does include some of the mass associated with particles larger than 10 (2.5) μm.

This issue of nominal values leads to a primary focus of this series of manuscripts, that is, industries that emit PM with a MMD less than or equal to 5.7 μm (MMD associated with EPA's definition of an urban dust) are not regulated at the same level as agricultural operations, which typically emit PM with an MMD much greater than 5.7 μm. This unequal regulation is primarily due to the interaction of the sampler performance and PSD characteristics. The initial manuscript in this series discussed this error in general terms. This manuscript will focus on defining these errors for the PM_{10} and $PM_{2.5}$ ambient air samplers.

PM_{10} Ambient Air Samplers

In order to define the differences in the simulated sampler measured and true PM_{10} concentrations, the driving equations were solved using Mathcad 2000 for a d_{50} equal to 10.5 μm, slope of 1.6, GSD of 1.5, and MMDs ranging from 1 to 40 μm. Results of this simulation are illustrated in Figure 1. In Figure 1, three MMDs are highlighted. The first corresponds to a MMD of 5.7 μm, MMD associated with urban dust as defined by EPA, and the other two correspond to the MMDs encompassing the range of MMDs expected from agricultural type dusts, MMDs of 15 and 25 μm. When comparing the sampled to true concentrations for the urban dust, the sampled concentration is about 9% [i.e. (true percent less than 5.7 μm – sampled percent less than 5.7 μm)/(true percent less than 5.7 μm)] lower than the true concentration. Further when comparing the sampled to true concentrations for the range of agricultural type dusts, the sampled concentrations were 75 to 700% [i.e. (true percent less than 15 μm {25 μm} – sampled percent less than 15 μm {25 μm})/(true percent less than 15 μm {25 μm})] higher than the true concentrations.

To further describe how the interaction of the PSD and sampler characteristics affect the acceptable PM concentrations, a series of calculations were performed in Mathcad 2000 to determine a range of errors associated with generate a data file containing the solutions to the driving equations over a range of parameters. These parameters included MMD values ranging from 1 to 40 μm (in increments of 1 μm), and GSD values ranging from 1.3 to 2.5 (in increments of 0.1). To illustrate the results of this simulation, several graphs were created to demonstrate how each of the parameters affects the concentration ratio.

In Figure 2, the GSD is held constant at 2.0 for the four sets of PM_{10} sampler performance characteristics, which define the acceptable concentrations for PM_{10}, and PSD MMDs ranging from 1 to 40 μm. To aid in the interpretation of the graph, an average concentration ratio is defined as the average of the largest and smallest ratio associated with the range of ratios defined by the sampler performance characteristics for a particular MMD. Conclusions that can be drawn from the information presented in this figure are: (1) the average ratio is less than 1 when $MMD<d_{50}$, (2) the average ratio is equal to 1 when $MMD=d_{50}$, (3) the average ratio is greater than 1 when $MMD>d_{50}$, and (4) the ratio range increases as the MMD increases. In general terms, when the ratio is less than 1 the current method of regulating PM_{10} underestimates the concentration of PM less than or equal to 10 μm AED and when the ratio is greater than 1 the current method overestimates the concentration of PM less than or equal to 10 μm AED. For example, if a PSD were characterized by a MMD of 10 μm AED and a GSD of 2.0 then the acceptable range of PM_{10} concentrations would be 142 to 158 μg/acm (i.e. ratios of 0.95 and 1.05 obtained from Figure 2 and multiplied by 150 μg/acm the current NAAQS for PM_{10}). However, if a PSD were characterized by a MMD of 20 μm AED and a GSD of 2.0 then the acceptable range of PM_{10}

concentrations would be 158 to 209 μg/acm (i.e. ratios of 1.05 and 1.39 obtained from Figure 2 and multiplied by 150 μg/acm the current NAAQS for PM_{10}).

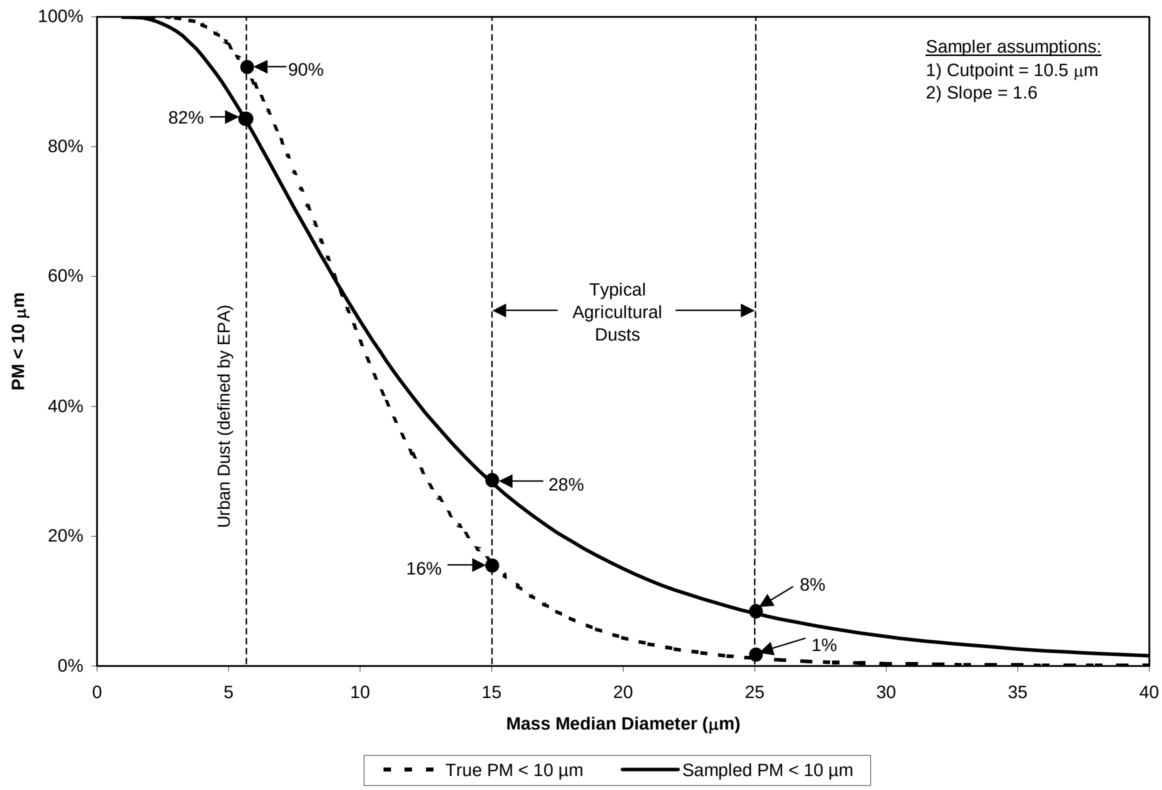

Figure 1. Comparison of true and sampled PM_{10} percentages for a range of PSD mass median diameters and a GSD of 1.5

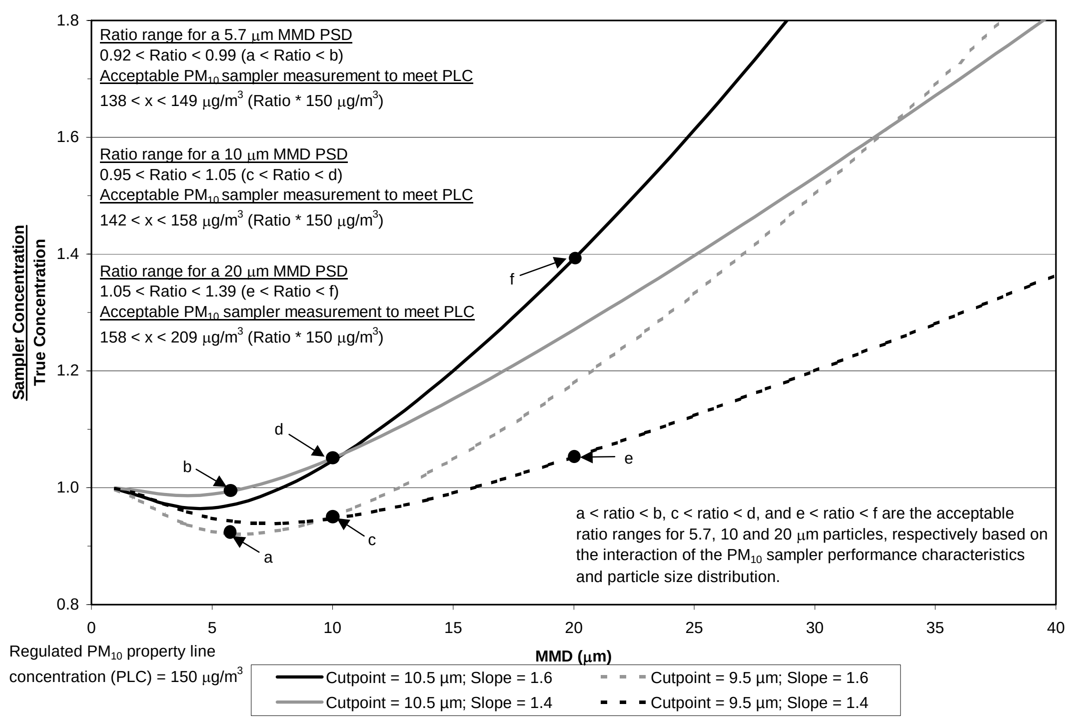

Figure 2. Theoretical ratios of PM10 sampler to true PSD concentrations (PSD – GSD = 2.0)

The data presented in Figure 3 are based on the same assumptions as Figure 2, except the data are based on a GSD of 1.5. When comparing Figures 2 and 3, it is obvious that the ratios increase much more rapidly as the MMD increases when the GSD is 1.5 as compared to a GSD of 2.0. For example, if a PSD were characterized by a MMD of 10 μm AED and a GSD of 1.5 then the acceptable range of PM_{10} concentrations would be 138 to 159 μg/acm (i.e. ratios of 0.92 and 1.07 obtained from Figure 3 and multiplied by 150 μg/acm the current NAAQS for PM_{10}). However, if a PSD were characterized by a MMD of 20 μm AED and a GSD of 1.5 then the acceptable range of PM_{10} concentrations would be 272 to 515 μg/acm (i.e. ratios of 1.81 and 3.43 obtained from Figure 3 and multiplied by 150 μg/acm the current NAAQS for PM_{10}). Another conclusion that can be drawn from the data presented in Figures 2 and 3 is that the range of acceptable concentrations increases as the GSD increases.

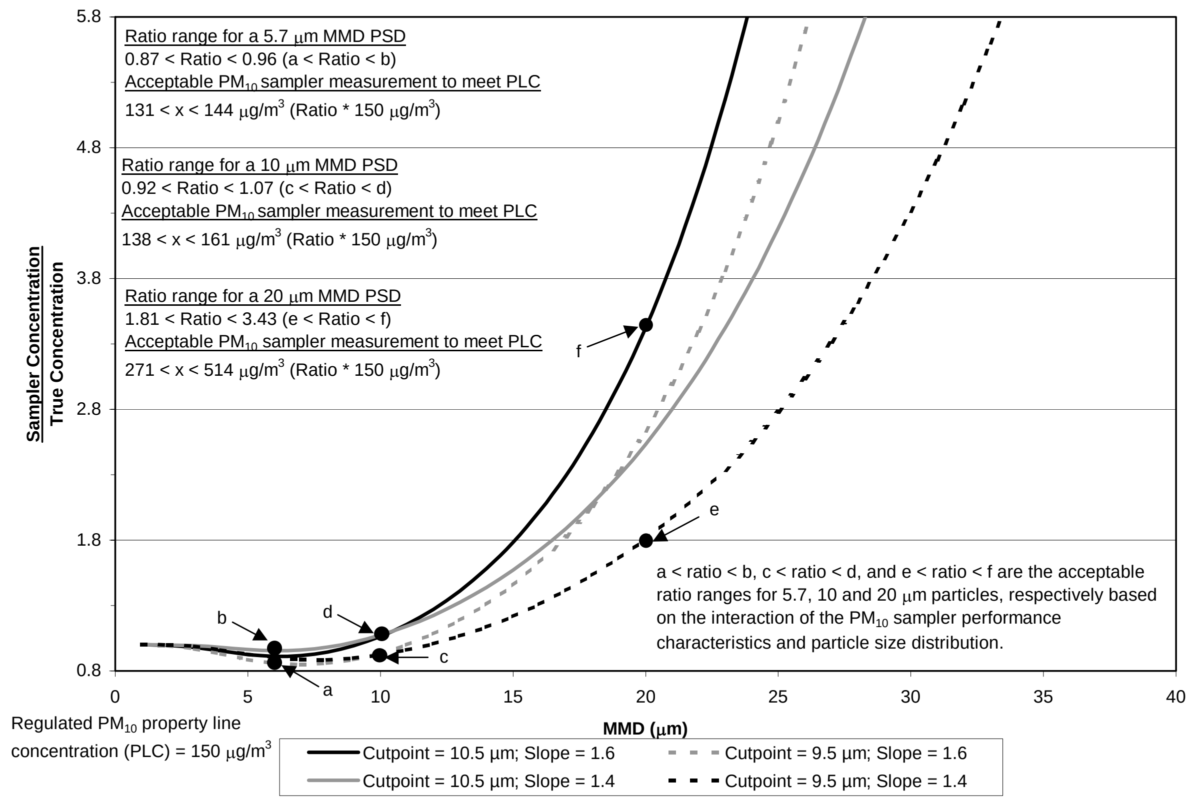

Figure 3. Theoretical ratios of PM_{10} sampler to true PSD concentrations (PSD – GSD = 1.5)

Figure 4 is a generalized graph to illustrate how MMD's and GSD's affect the concentration ratios for a PM_{10} sampler with a d_{50} of 10.0 μm and a slope of 1.5. The general observation that should be made from this graph is that the concentration ratios decrease (ratio approaches 1.0) as the GSD increases. Figure 5 further expands on how the concentration ratios are impacted by GSD. The data presented in Figure 5 are based on MMDs of 10 and 20 μm, sampler performance characteristics of d_{50} = 9.5 μm with a slope of 1.4 and d_{50} = 10.5 μm with a slope of 1.6, and variable GSD's ranging from 1.2 to 3.0. The general conclusions that should be drawn from this graph include: (1) when the MMD is equal to the d_{50} the range of concentration ratios is centered around 1.0 for all GSD's, (2) as the GSD increases the concentration ratio decreases and approaches 1.0, and (3) as the GSD decreases the concentration ratio increases and approaches infinity for an MMD of 20 μm AED.

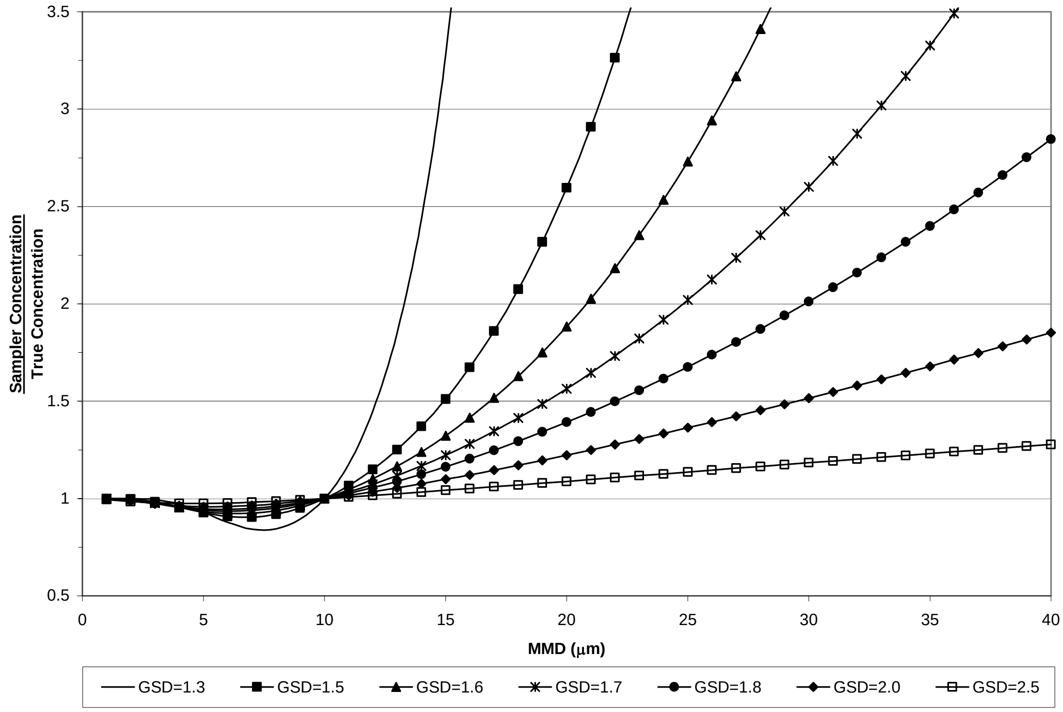

Figure 4. Theoretical ratios of PM_{10} sampler to true PSD concentrations (PM_{10} sampler characteristics; cut-point = 10 μm and slope = 1.5)

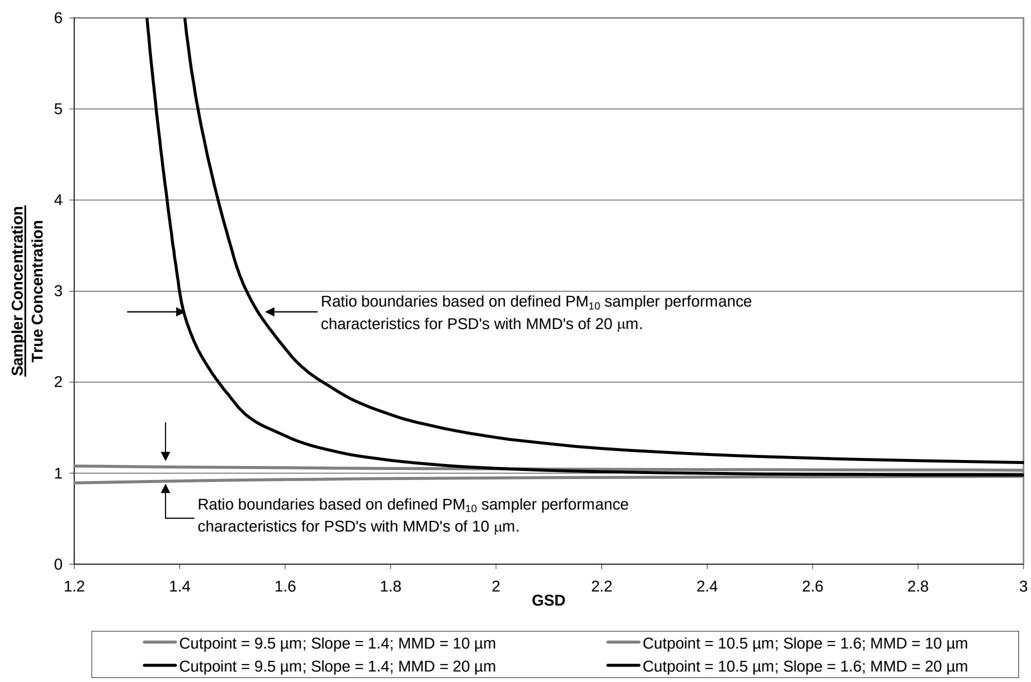

Figure 5. Theoretical PM_{10} sampler to true concentration ratio boundaries based on varying GSDs for PSD's with MMDs of 10 and 20 μm

Summary and Conclusions

There are several errors associated with the current air pollution rules and regulations established by EPA, which should be minimized to assure equal regulation of air pollutants between and within all industries. Potentially, one of the most significant errors is due to the interaction of the industry specific PSD and sampler performance characteristics. Currently, the regulation of PM is based on sampler measurements and NOT true concentrations. The significance here is that sampler concentrations do not account for all the mass associated with the particle diameters less than the size of interest and further, sampler concentrations include a portion of the mass associated with particle diameters greater than the size of interest. The alternative to this method bases the regulations on a true concentration, which would account for all the mass associated with the particle diameters less than the size of interest and would not include mass associated with particle diameters greater than the size of interest.

What is the impact of this error? The following example demonstrates. Assume:

- PSD associated with a coal-fired power plant is described by a MMD = 10 µm and a GSD = 1.5;
- PSD associated with a agricultural operation is described by a MMD = 20 µm and a GSD = 1.5;
- PM is currently regulated in terms of PM_{10} sampler concentrations with a maximum property line concentrations limit of 150 µg/acm;
- PM_{10} ambient air sampler performance characteristics are described by a d_{50} = 10 ±0.5 µm and a slope of 1.5 ± 0.1.

Based on the current method of regulating PM_{10}, both the coal-fired power plant and the agricultural operation must not exceed the property line PM_{10} concentrations of 150 µg/acm (based on sampler measurements), in order to maintain compliance with the regulations. The current method of regulation does NOT account for errors associated with sampler performance characteristics or errors associated with the interaction of the industry specific PSD and sampler performance characteristics. In order to adequately account for these errors, the concentrations must be established based on true concentrations and the sampler performance characteristics that produce the largest concentration levels. In other words:

- the PM_{10} ambient air sampler performance characteristics that should be used are a d_{50} of 10.5 µm and a slope of 1.6; and
- a true concentration (150 µg/acm for PM_{10}) should be used, meaning that if PM_{10} concentrations are determined by the corresponding size specific samplers that the measured concentrations must be corrected to represent true concentrations;

After adjusting the concentrations for these errors, the following results are obtained:

- For the coal-fired power plant, a PM_{10} sampler could measure concentrations as high as 159 µg/acm and still comply with the regulations. This results in a 6% error due to the sampler performance characteristics.
- For the agricultural operation, a PM_{10} sampler could measure concentrations as high as 515 µg/acm and still comply with the regulations. This results in a 243% error due to the sampler performance characteristics and interactions of the PSD and sampler performance characteristics.

Results of the analysis presented in this manuscript show that not all industries are being equally regulated in terms of PM and that **ALL** industries should be concerned with the current site-specific regulations implemented by EPA and enforced by SAPRA's.

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Measuring Ammonia Emissions from Agricultural Practices

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Introduction:
Ammonia (NH_3) emissions from fertilizer applications and dairies may be significant contributors to the San Joaquin Valley, CA, air problem. Over the past five years we have been monitoring ammonia emissions from various agricultural operations in the San Joaquin Valley, California (Krauter, 2001; Krauter et al. 2001, 2002 & 2003; Potter et al., 2001). Our current research involves the use of two different ammonia sampling systems- filter packs and tunable diode lasers (TDL) (Fitz et al., 2003; Goorahoo et al., 2001; Beene et al., 2002 & 2003; Carstensen et al., 2004). Firstly, we will review the technology involved in the use of active filter packs and the open path tunable diode laser (TDL) for monitoring ammonia emissions. Then we will present examples of our research data collected to highlight the applicability of the filter packs for measuring NH_3 emissions from fertilizer applications and the TDL for monitoring diurnal and seasonal fluctuations of ammonia during various dairy management practices. We conclude the presentation with a discussion on the potential use the TDL data for validation and assessment of the U.S. Environmental Protection Agency (EPA) model for predicting downwind concentrations from area sources.

Active ammonia sampling filter packs:
For our projects aimed at monitoring NH_3 emissions from fertilizer applications we have been using mainly the active chemical filter pack systems to collect the atmospheric NH_3. Basically, the filter pack, sometimes referred to as a denuder, is a device that pulls air through a treated medium that changes the NH_3 to a solid. Glass filters are impregnated with 3% citric acid in 95% ethanol solution. The NH_3 forms ammonium citrate on the treated filter. In the laboratory, the micro-grams (*u*g) of NH_3 on the filters are determined by dissolving the ammonium in de-ionized water and measuring the concentration using Nessler reagent and a spectrophotometer.

In the field, air is pulled through the ammonia filter pack using a 12V battery powered pump, and so this technique is referred to as **active sampling**, as opposed to a **passive sampling** system.

A major requirement of our research is the measurement of a vertical profile of ammonia levels to characterize the relationship between the soil/vegetation surface and the atmospheric NH_3. To that end, multiple filter packs are mounted on a tower or mast for simultaneous sampling at various elevations. Currently, five systems with a 10m mast have been constructed and one tower of 20m was built on a trailer. The filter packs require several hours of sampling to acquire sufficient NH_3 for detection in the laboratory. Our initial work indicated a diurnal difference in atmospheric NH_3 levels so sampling is generally continuous with the filter packs changed at dawn and dusk.

Tunable Diode Laser systems:
The filter pack method for collecting atmospheric NH_3 requires several hours to collect a sample in most instances. That time period is too long to characterize short term operations such as those at dairies where a process occurring over a few minutes may produce significant NH_3 emissions that would not be detectable over the long sampling period of the filter packs.

The TDL system measures gas concentration over an open path. It consists of an integrated transmitter/receiver unit and a remote, passive retro-reflector array. The transceiver houses the laser diode source, the drive electronics, the detector module, and microcomputer subsystems.
The laser light emitted from the transceiver unit propagates through the atmosphere to the retro-reflector and returns to the source, where it is focused onto a photodiode detector. A portion of the laser beam is passed through an onboard reference cell to provide a continuous calibration update.

Initially, atmospheric NH_3 was monitored in the laboratory using a TDL for open-path spectroscopy. Presently, we utilize both fixed and portable TDL systems. The fixed system is installed in a trailer and has been used at field sites for short term, real-time monitoring of NH_3. When testing and installation is completed, the system will enable NH_3 to be monitored simultaneously on five paths at distances up to 500m from the laser source. There are small TDL units that are also available for portable, field monitoring of one gas on a single path. These are proven field units that are an EPA approved monitoring method for a variety of gasses.

Meteorology systems:
From the data collected with both the filter pack and TDL systems, it is possible to determine the mass of NH_3 in a known volume of air. The significance of that concentration depends upon the wind speed, which can be quite variable near the soil/vegetation surface, and over dairy lagoons. Therefore, for each set of filter pack and TDL measurements we measure or calculate wind speed value for that sample height. The sampling masts and tower used for the filter packs also have anemometers mounted at most sampling points to monitor the wind profile. Hence, NH_3 levels may then be correlated with other meteorology factors the sampling systems monitor air and soil temperature, relative humidity, solar radiation and rain fall.

Emissions from fertilizer applications in cotton measured with filter packs:
Ammonia emissions were evaluated during two anhydrous ammonia fertilizer application methods from a crop of cotton. The first method evaluated was a side-dress application of anhydrous ammonia shanked into the soil. This sampling was conducted during two seasons and while three different rates of nitrogen fertilizer were tested. The rates included a high, low, and variable rate of the fertilizer. The variable rate of nitrogen is sensitive to the changing yield potential of the soil. The previous years yield data is used to create a fertilizer prescription map. The sampling method used during the side-dress applications were active chemical filter packs mounted on a 10 meter tower with sampling locations at

.5, 1, 2, 4, and 10m. Anemometers were co-located at each sample height while temperature and relative humidity were also logged. The second application method evaluated for fugitive ammonia emissions was a water run application of anhydrous ammonia in which the fertilizer is bubbled into the head ditch of the irrigation system and allowed to flow in the field in the irrigation water. Monitoring of the water run application was done with active chemical filter packs and open path tunable diode laser during three days of the water run application. Sampling sites were directly upwind and downwind of the field in order to obtain a net downwind concentration. Results from the side-dress application indicate higher rates of anhydrous ammonia fertilizer correlating with higher amounts of ammonia emitted. Evaluation of the water run application showed an enrichment of ambient concentrations of ammonia downwind of the field.

Emissions from dairy lagoon measured with TDL:
California is the number one dairy state, producing 26 billion pounds of milk and cheese (CDFA, 2003). Most of the dairy operations in California are concentrated in the San Joaquin Valley (SJV). While the growth of this industry results in significant economic returns for the region, there is the issue of effective manure management. Major problems associated with the manure management are high solids and nutrient contents of the effluent stream, and gas production during the decomposition of manure in storage. As a result the health, environmental and economic concerns, there is a need to quantify the NH_3 emissions at dairies. Furthermore, the spatial and temporal distribution of these gases on the farm should also be investigated. A first step in obtaining these emissions is to determine real time concentrations of these gases.

In this phase of our study, conducted over 20 months, on dairies representing management practices typical of dairies in the SJV, the applicability of TDL technology in determining gas emissions at the dairies was assessed. The first four months of the project were devoted to development of methodologies and protocols for sampling the gaseous emissions in real-time. Then for the remainder of the project duration, the lagoons and free-stall areas at these dairies were monitored for both diurnal and seasonal fluctuations in the emission of NH_3. Real time measurements of gas concentrations were correlated with Oxidation Reduction Potential (ORP), pH and dissolved oxygen (DO) of the lagoon water.

Assuming that the TDL instruments are kept within optimum operating temperature conditions, the TDL technology is suitable for detecting the gas emissions from dairy lagoons during the summer temperatures typical of the San Joaquin Valley, CA. However, during intense fog observed during the Fall and Winter seasons, the lasers fail. The TDL technology permitted the correlation of the gas fluctuations with management practices such as aeration, agitation, lane flushing, acidification and recycling of fresh water into the dairy lagoons and subsequent application to surrounding fields. Generally, as the pH of the lagoon dropped from 8.0 to 6.5, average NH_3 fluxes decreased from approximately 1.6 to 0.5 mg m^{-2} s^{-1}. Overall, NH_3 fluxes decreased when the ORP was increased from -250mV to -100mV. It is essential to conduct monitoring during the fall, winter and spring seasons to assess the performance of the TDL system under these conditions, while at the same time examining any seasonal variability in the gaseous emissions

Comparison of active filter packs and TDL measurements at dairies:

Due to the fugitive nature of emissions at dairies the emissions of pollutants cannot be directly measured. Therefore in order to determine the magnitude of NH_3 emissions, ambient monitoring and modeling must be used. This requires measuring ambient concentrations precisely and then using those concentrations in a model to determine emission rates. There are several methods that can be used to determine the ambient concentration of ammonia in the air. Concurrent measurements were made in the field along with applicable meteorological data in order to use the integrated horizontal flux method as well as the EPA approved model, Industrial Source Complex-Short Term version 3, for emission factor development.

An attempt was made to use the data collected with the TDL in an EPA approved model to predict downwind concentrations from area sources. However, due to the limited number of laser units available we are currently unable to obtain simultaneous upwind and downwind concentrations. This presents the problem of determining what portion of the measured concentration downwind of a source is attributable to that source. Nonetheless, by adopting a 3-phased sampling scheme, we should be able to use the TDL data for validation and assessment of the EPA model for predicting downwind concentrations from area sources. Generally, the data collected with the TDL depicted the periods of relatively higher emissions occurring during the day and night times which generally go undetected with the filter pack sampling.

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Session III

Pest Management

Session Chairs:

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Consumer Response to Bt Sweet Corn in a Politically-Charged Environment

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Introduction

Concerns about genetically enhanced foods are growing in the awareness of consumers in the United States and Canada (James et al. 2002, James 2004, Powell et al. 2003). It is still unclear, however, how these concerns are affecting consumer purchasing decisions (James et al. 2002, James 2004). In June, 2004 we began a two-fold investigation to: 1) determine if there is a pest management advantage to growing a genetically enhanced variety of sweet corn compared to the conventional variety and 2) would the consumers who have traditionally bought Cal Poly sweet corn purchase the product knowing that it is genetically enhanced. This paper describes our experiences during this investigation.

The collection of data for the investigation was complicated by the inclusion of Measure Q on the November ballot in San Luis Obispo County. This measure would have made it "unlawful for any person or entity to propagate, raise, or grow genetically engineered organisms in San Luis Obispo County" (SLO GE Free, 2004).

The public campaigns for and against Measure Q affected this investigation. The roles of the authors were also affected as public attention became drawn to the investigation. Growers, agricultural consultants, extensionists, and university researchers should be aware of how a public campaign addressing biotechnology in their community will likely affect them.

Phase One- A scientific approach to answering questions

During the course of the investigation we experienced three distinct phases. Phase One was characterized by the lack of influence and interaction from anyone outside of the university.

At Cal Poly SLO students pursuing degrees in agricultural fields are required to participate in an "Enterprise Project." Student Enterprise Projects are small-scale farming projects designed to give students the experience of planting, growing, harvesting, and then marketing a crop. One of the most popular crops that has been grown and sold by Cal Poly students is sweet corn. The season for sweet corn grown at Cal Poly SLO is limited by corn earworm damage which increases as the season progresses.

We designed a research project to answer the following questions of students and professors:

1. Can planting biotech varieties extend the sweet corn season?
2. Will planting biotech varieties reduce pesticide use?
3. Will planting biotech varieties reduce pest damage to the product?
4. Will consumers accept a biotechnology food product in place of the conventional variety?

A field experiment using a factorial Randomized Complete Block Design comparing biotech and conventional sweet corn varieties, both treated with insecticides and untreated, was planted in July, 2004 to investigate questions 1, 2, and 3 above.

A sales data collection project was designed to investigate question 4 above using the work of James et al. (2002), Powell et al. (2003) and input from Cal Poly SLO social science faculty as a guide. The corn would be offered for sale through the local outdoor Farmers' Market and a locally-owned upscale grocery store. Only data from our sales at the Farmers' Market will be discussed in this paper.

Farmers' Market Sales, Survey, and Interviews

Four sweet corn products were offered to the public at the Thursday night San Luis Obispo Farmers' Market in downtown San Luis Obispo on two dates. The products were displayed on a table with placards reading "Biotech, Sprayed," "Biotech, Not Sprayed," "Conventional, Sprayed," "and "Conventional, Not Sprayed."

On the first date (Sept. 30, 2004) the corn was offered for sale. A single placard indicated the price to be "4 ears / $1". Sales data were collected for the number of subjects purchasing corn and how many ears total were sold by category.

On the second date (November 18, 2004) the four products were displayed with the same placards indicating category, but the ears were not sold. Instead, subjects who approached the booth were asked the question: "If you were purchasing sweet corn tonight, which of these products would you choose?" The subject's choice was recorded.

The subject was then asked: "What factors affected your choice?" The subject's response was recorded by hand as accurately as possible. If the subject offered further information about their views of biotech food products these comments were also recorded. This data was coded by the descriptors listed in Figure 1.

The limitations of this data collection method are many. Conclusions drawn from this data must be bounded by the self-selection of subjects to participate, the small sample size (date 1 N=21, date 2 N=62), the demographics and preferences of shoppers at a Farmers' Market, and the activities of political action committees both for and against the ballot measure engaging the shoppers at the same event.

Interview Responses

When subjects identified the most important factors in their choice of sweet corn products three qualities were mentioned by more than 15% of respondents: "Appearance" (36%), the subject "prefers organic" products (24%), and the "Quality" of the product (18%). "Appearance" was coded for responses related to insect damage as this damage was obvious in several of the products and subjects generally responded negatively to those ears, although a few subjects indicated that insect damage was a sign that the product was "natural" or free of pesticides. Responses related to kernel size, ripeness, etc. were coded as "Quality."

Concerns expressed by subjects regarding biotechnology were mixed. 11% of respondents expressed concern that the impacts of biotech food products are not know while 11% expressed concerns about the impacts of pesticides. 8% of subjects stated they would not eat a genetically modified food product while 8% expressed that biotechnology is a necessary technology to feed the world. Respondents mentioned other concerns both for and against biotech food products including health, nutrition, evaluations of the relative impacts of pesticides versus impacts of biotechnology, price of the product, corporate control of the food supply, lack of testing and pest resistance.

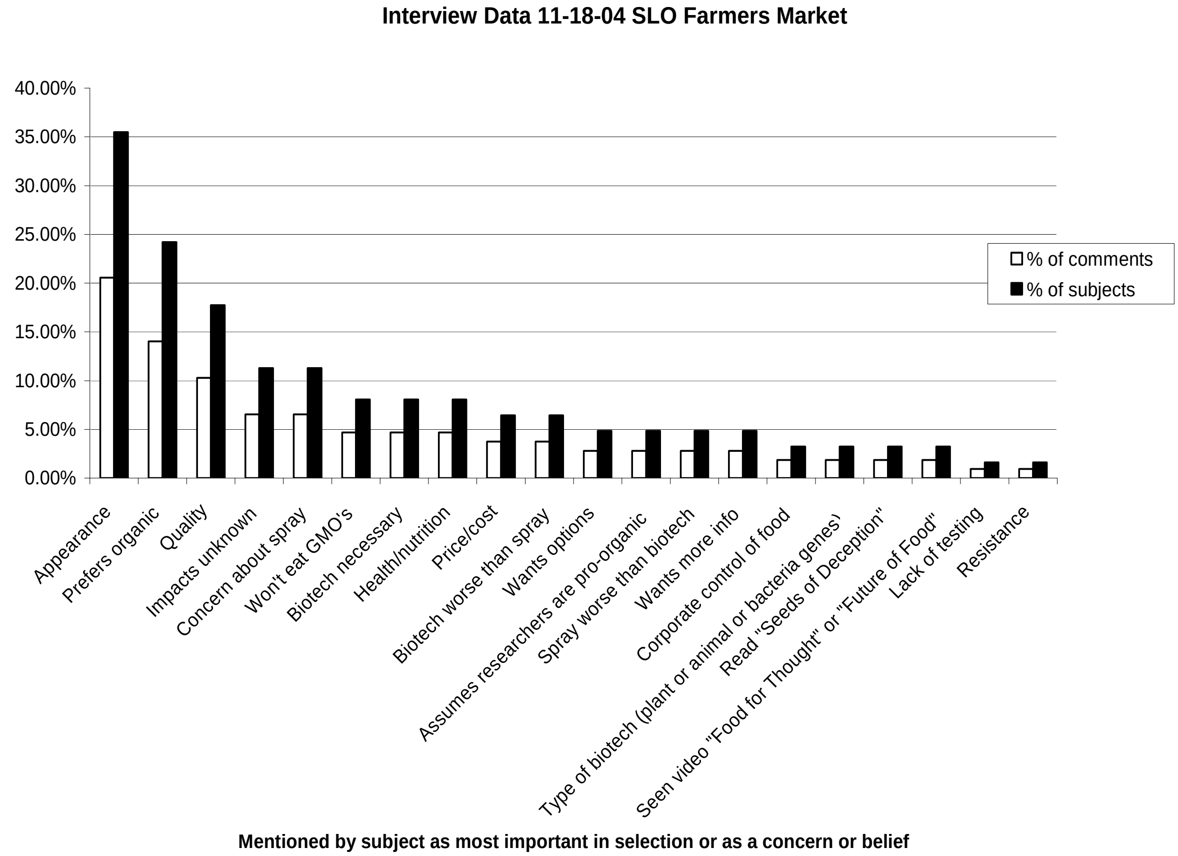

Figure 1.- Interview data

Phase Two- Public Debate of Biotechnology

Phase Two was characterized by the introduction of Measure Q, a ballot initiative which would have made it "unlawful for any person or entity to propagate, raise, or grow genetically engineered organisms in San Luis Obispo County" (SLO GE Free, 2004). This event forced voters in San Luis Obispo County to evaluate their attitudes toward biotech food products. As the public debate over the measure evolved two distinct camps became organized into campaigns: activist with concerns and fears about the safety, both nutritional and environmental, of biotechnology crops and producers who did not want to lose the option of using biotechnology to solve pest management challenges in the future (Committee to Support measure Q, 2004, Citizens for a Sustainable Future/No on Q, 2004).

As the election approached, both camps engaged us in efforts to redefine the university's role in the community from unbiased scientific researchers to that of advocates for biotechnology or as proxies for biotechnology corporations or other adversaries. Neither campaign used the university as researchers and educators who can provide unbiased, factual information to the public to help them make an informed decision regarding a public policy issue.

The political framing of the issues under investigation required/produced actions by all the parties described above substantially affecting the progress of the investigation. The questions formulated in Phase One can be investigated scientifically using very simple methodologies. The question of consumer acceptance of the biotechnology product was cast in a new light in Phase Two requiring a more rigorous economic and sociological methodology. Simply collecting data comparing the sales of the two products seemed inadequate to truly gauge consumer acceptance of the products given the increase in awareness of biotechnology as a public policy issue. The question became "Will consumers accept a biotechnology food product in a politically-charged environment?" Investigating this question requires more sophisticated, complicated, and time-consuming social data collection methods than the authors were prepared to execute during the summer of 2004. With the guidance of Dr. Jennifer James of Penn State University and Cal Poly social science faculty a survey/interview component was added to the sales data collection part of the investigation.

With adequate funding and more time for design and planning the question of consumer acceptance of the products can be investigated scientifically using established methodologies from sociology and experimental economics. The authors hope to perform this work in the future.

During Phase One data collection appeared to be a relatively simple task. The development of Phase Two presented two possible obstacles to successful data collection:

1. Will someone destroy the field? This happened to an experiment conducted by one of the authors during his doctoral research at UC Davis.
2. Will the discussion of the measure, regardless of passage, skew sales data?

Phase Three– The Election

Phase Three was characterized by the use of traditional campaigning techniques by two political action committees- the Committee to Support Measure Q and Citizens for a Sustainable Future/No on Measure Q. These two organizations became increasingly active during September and October as the election approached.

The election cycle is an example of the "advocacy model" (Barron & Fiske, 1993). The structure of resolving conflicts using the advocacy model has the following form familiar from the parliamentary procedure used by democratic governments and other decision-making entities:

1. Resolved: Ban the production of biotechnology crops in San Luis Obispo County.
2. Advocates Pro and Con publicly debate the resolution.
3. The electorate votes to adopt or reject the resolution.

Another indicator contradicting the assumption that consumers are concerned about the negative impacts of biotechnology is the final vote count on the measure. 93% of voters participating in the election voted on Measure Q (SLO County Office of the Clerk-Recorder) indicating that at least 121,356 citizens of San Luis Obispo County are concerned about the issue. However, 59% of those voting on the measure voted against it, contradicting the belief that citizens of San Luis Obispo County believe the negative impacts of biotechnology outweigh the benefits.

Implicit in the actions of both campaigns was the assumption that education will affect changes in the views and actions of the electorate. This appears to be a very reasonable assumption, but the education efforts of both campaigns took a distinctly propagandistic orientation. Inaccurate and misleading information regarding biotechnology was disseminated by both campaigns (Committee to Support measure Q, 2004, Citizens for a Sustainable Future/No on Q, 2004).

We were called upon by both campaigns to participate in the debate on a variety of levels. Providing unbiased factual information was not one of the roles requested. The proponents of the measure treated us as advocates for biotechnology. Being cast in this role by an active political group led to the appearance that the university as a whole is an advocate for biotechnology, undermining the acceptance by the public of information provided by the university as factual and unbiased.

Presumably members of the political action committees that ran the campaigns had made a decision regarding the issue and would not be swayed by the educational efforts of their opponents. Therefore the question is: "Did education efforts sway undecided voters?" Comments recorded from the survey and interview data suggest that voters were swayed by the information presented by the campaigns. These comments suggest that voters were influenced both for and against the measure by information presented by both campaigns. A more rigorous methodology would need to be applied to this issue to determine the effect of the education efforts of both campaigns.

Outcomes of the Debate, Conclusions and Recommendations

During Phase Three a number of values, beliefs, and attitudes were expressed during the public debate, especially at public forums discussing the issue. Representatives for grower organizations indicated that they should have had a hand in drafting the measure. Consumers indicated that they should have a choice about how their food is produced. Activists stated that the public should be consulted when evaluating the risks and benefits of a new technology. These three positions are not mutually exclusive or in conflict in any way. It may be in the best interest of the community to respect all three of these positions. A collaborative model for addressing this issue in San Luis Obispo County may have brought these views to light earlier in the process making cooperation and compromise possible.

One proposed collaborative approach that was discussed during Phase Three was to create a mechanism for the community to accept or reject biotechnology applications in the county on a case by case basis taking local needs and conditions into account. Such an approach would address the needs and concerns of growers, consumers, and activists.

The San Luis Obispo County Board of Supervisors did address this issue earlier in the year (April 6th.) in response to a request to grow a genetically engineered pharmaceutical rice variety in the county. This request was rejected by the California Department of Food and Agriculture. On April 20, 2004 the Board of Supervisors directed the Agricultural Commissioner to form a committee to investigate the issue of biotechnology and report back with more information. Shortly after the formation of the committee petitions to put Measure Q on the ballot began to circulate. The Agricultural Commissioner submitted the committees report and his recommendations to the Board of Supervisors on August 3rd., 2004.

Why didn't this collaborative structure prevent the advocacy model of a ballot initiative from occurring? An investigation of the motivations of the political action committees active in the campaign would be required to answer that question.

Under the collaborative model the university can address these questions and concerns by providing education with current scientific and policy information without appearing to promote, defend, or have conflicts of interest with the issue. In this role Cal Poly SLO could have fulfilled its stated mission to: "…discover, integrate, articulate, and apply knowledge…(by)…teaching; engaging in research; participating in the various communities, local, state, national, and international, with which it pursues common interests…(Cal Poly SLO)."

It is not the role of the university to move the model from advocacy to collaborative. The actors have to choose (Barron & Fiske, 1993). Changing the model can be a role played by local government, but in this case, the formation of a committee to address the issue by the Board of Supervisors was ineffective at moving the process to a collaborative model.

The university is an important resource that can provide service to all citizens of the community. We would have preferred to have played that role in this debate. Was this the case in our experiences with Measure Q? No.

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Horseweed and Hairy Fleabane: Recognition and Management in Orchards and Vineyards

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Introduction

Horseweed or mare's tail (*Conyza canadensis*) and flax-leaved or hairy fleabane (*C. bonariensis*) are fast becoming major weed problems for tree and vine growers in California. While they are commonly found throughout the state, they are especially troublesome in orchards and vineyards in the southern San Joaquin Valley. Observations during 2003/03 suggest that raisin vineyards have shown the greatest increase in horseweed and hairy fleabane populations. This may reflect the attempts of many growers to reduce their weed control inputs to reduce production costs in response to diminished crop values of recent years. Reduced uses of effective pre-emergence herbicides, reduced rates of post-emergence herbicides, and delayed post-emergence applications have also contributed to the problem. There are also reports from other states and around the world that horseweed and hairy fleabane have developed resistance to several important herbicides commonly used in California, including glyphosate, paraquat, and simazine. To prevent their further spread, and get a handle on control, it is essential for growers, PCAs, and managers to understand the biology of these weeds and control strategies available.

Biology and Identification

Horseweed and hairy fleabane are summer annual weeds belonging to the Asteraceae (sunflower) family. They reproduce solely by seed, which typically germinate from late-fall through spring, grow vegetative during the summer and mature and produce new seed from July through September. It is common to find both species growing in the same vicinity. At the earliest stages of growth, both weeds look similar, but as they mature, their differences become apparent. Table 1 provides some key differences in plant characteristics to help identify the two species.

Horseweed and hairy fleabane produce large amounts of seed per plant (100,000+ and 10,000+ respectively) that are disseminated by wind, accounting for their rapid spread. According to studies conducted at Penn State University, mature horseweed seed can travel ¼ mile or more. Another reason for its rapid spread is the ability of the seed to sprout without having to undergo dormancy. In many cases, as seed falls to the soil, new plants can be seen emerging from within the vicinity within a few weeks if conditions favor germination. These weeds prefer undisturbed situations, such as tree or vine rows that are not tilled, which are easily warmed during sunny parts of the day. Seed burial through cultivation and debris on the soil surface discourage germination. Perhaps one thing going in the favor of growers is that seed survival is short (3 years or less) under most conditions.

Table 1. Key characteristics of horseweed and hairy fleabane

Characteristics	Horseweed	Hairy fleabane
Leaves	Seed leaves dull green, oval, covered with soft, fine hairs. True leaves dark green with fine toothed margins, forming a compact rosette. Lower leaves inversely lance shaped, usually serrated margins, with short stalks. Upper leaves more narrow, without stalks, smooth around the margins, alternate and crowd around the stem, up to 4" long	Seed leaves dull green, oval, covered with soft, fine hairs. True leaves light or dull green, somewhat crinkled. Mature leaves narrow, crinkled, grayish in color, slightly toothed around the margins, less than 3" long.
Mature plant	Erect, single stem, up to 10' tall, somewhat rough to the touch, with shaggy hairs.	Multiple branches, without a central stem growing 1½ to 3' tall, hairy.
Flowers	Small, yellowish flower heads at the ends of branched stems at the top of the plant.	Small, yellowish flower heads at the ends of branched stems at the upper part of the plant.
Seed	Tiny, narrow, tan colored, with firm grayish hair (pappus) at the upper end. Up to 230,000 per plant produced.	Tiny, narrow, tan colored, with firm grayish hair (pappus) at the upper end. 10,000 or more per plant produced.

Losses Caused

These weeds compete significantly for water and nutrients, especially where low-volume surface drip or micro-sprinkler irrigation is used. They are particularly competitive during the first few years of crop establishment. In newly planted orchards and vineyards, they can reduce vigor and delay maturity. While they may not necessarily reduce tree or vine growth in mature fields, they continue to compete for valuable resources. In addition, these plants can impede with daily activities, including spraying and harvest. Horseweed is also known to be a host for the Glassy-winged sharpshooter (a vector of *Pierce's Disease* in grapes and *Leaf Scorch* in almonds). Under high populations, these weeds may increase the humidity, which might interfere with the drying process of dried on the vine (DOV) raisins. Where continuous tray systems are used for drying raisins on the soil surface, seeds from mature plants can land in the folds of drying raisins and contaminate them.

Control Strategies

The critical first step for managing horseweed and hairy fleabane is to recognize you have these weeds and limit their further spread. Control options should be implemented with an understanding that all efforts should be directed toward the prevention of new seed. The two best times to control these weeds are before they emerge (preemergence herbicides where appropriate) and when they are in their seedling stage of growth (prior to bolting). Both mechanical and chemical means are available for control. While none alone will resolve the problem over-night, they can have a significant impact over time if timed and used appropriately.

Mechanical - Numerous in-row equipment are available that can be used to control these weeds in a number of orchard and vineyard crops. Time the operation when these weeds are at the rosette stage of growth or sooner (less than 4" across). The best control is achieved when the soil is slightly moist, allowing for the top 2-3" of the soil to be disturbed and the weeds dried out. Tilling, mulching, or disking deeper than 3" or under dry or wet conditions can increase the chance of the plants surviving with clods of soil still intact. Effective mechanical equipment include the Clemens weed blade, Bezzerides, Kimco and L&H in-row tillers, Weed Badger, L&H hoe plow, Donnovator, and many others. Propane flaming and mowing are not generally considered effective options for these particular weeds. In most cases, mowing encourages lateral branching from the base of the plants, hardening them off. This makes control with post-emergent sprays nearly impossible.

Herbicides- Several pre- and postemergence herbicides are registered in tree and vine crops in California that can provide effective control of horseweed and hairy fleabane (table 2). Always read and follow herbicide labels for proper use recommendations. Pre-emergence herbicides should be applied before the weeds emerge from the soil. In all cases, incorporation by rainfall or irrigation water is required to activate the chemicals for adequate control. If weeds are present at the time of spraying, an appropriate post-emergence herbicide should be added to the tank.

If horseweed and/or hairy fleabane are expected to be present in a newly established field, use non-bearing preemergent materials like isoxaben and thiazopyr to help reduce their population before they become a problem in mature fields. Once established, use preemergence herbicides registered for bearing crops (refer to label for length of establishment), like bromacil, simazine, diuron, and oxyfluorfen to help reduce populations. Special permits are now required in California when using certain herbicides (like simazine, diuron, and bromacil) in Ground Water Protection Areas (GWPA). Permits for using these and other restricted herbicides are issued at local county Agricultural Commissioners offices.

Since these weeds often have multiple flushes per year, it is unlikely that a single postemergence spray will control them for the season. Which ever postemergence herbicide(s) you use, time your sprays according to the schedule of these weeds, not your own. This may require several applications during the season. As discussed with mechanical control, postemergence treatments will only be effective when these weeds are in their seedling stages of growth. Once horseweed or hairy fleabane gets much larger than 6” tall, control is significantly reduced. A tank-mix of 2,4-D and Roundup can provide excellent systemic control of these and other weeds when they are small. Adding ammonium sulfate at 5-10 lbs/100 gal of water to this mix can help improve control, especially where hard water is used. Glufosinate (Rely), a relatively new herbicide also provides effective burn-down control of these weeds when treated at a young age.

Table 2. Herbicides registered in California for horseweed and hairy fleabane control

Pre-emergence	Lb a.i./A	Control	Post-emergence	Lb a.i./A	Control
bromacil (Hyvar X)	4.8	C	diquat (Reglone)	1.0	P
bromacil+diuron (Krovar)	4.8	C	glufosinate (Rely)	1.0	C
diuron (Karmex, Direx)	2.4	P	glyphosate (Roundup, etc.)	1.0	C
EPTC (Eptam)	2.1	P	oxyfluorfen (Goal)	0.25 - 0.5	P
isoxaben (Gallery T&V) - NB	1.0	C	paraquat (Gramoxone, etc.)	2.0	P
norflurazon (Solicam)	2.0	P	sulfosate (Touchdown 5)	1.0	C
oxyfluorfen (Goal)	1.0	P	2,4-D amine (Dri Clean, etc.)	1.4	C
simazine (Princep Caliber 90)	2.0	C	2,4-D amine + oxyfluorfen	1.4 + .125	C
thiazopyr (Visor)- NB*	1.0	P	glyphosate + oxyfluorfen	1.0 + .125	C
simazine + diuron	1.5 + 1.5	C			

NB = non-bearing only and NB* = bearing and non-bearing citrus, non-bearing all others
C = acceptable control and P = partial control (effective control assumes timely application)

Glyphosate Resistance

Glyphosate-resistant horseweed was first reported in the United States in Delaware in 2000. Since then, there are nearly ½ million acres in the Midwest and East known to have resistant horseweed. This has been documented primarily where glyphosate-resistant crops (like soybeans, corn, and cotton) and/or conservation or reduced tillage production have been used for a number of years. Glyphosate-resistant hairy fleabane has also been documented in South Africa. While there are no reported cases of horseweed or hairy fleabane resistance to glyphosate in California *yet*, it is thought to exist. Studies are currently underway in the southern San Joaquin Valley to determine whether this resistance is currently present and how wide-spread it might be. Some growers in California have reported having the need to increase the amount of glyphosate used to maintain control of these weeds, while others have reported seeing occasional plants completely unfazed by their glyphosate treatments. Either of these cases might be an indication of glyphosate-resistance developing.

Summary

There is little doubt that horseweed and hairy fleabane populations are on the increase in California, especially in the southern San Joaquin Valley. To help resolve this problem, growers need to be aware it is occurring and implement a plan of attack as soon as possible. Early recognition of these weeds, timely control with appropriate mechanical and chemical means in and around field margins, and preventing new seed from forming are all essential components for successful eradication. Encouraging those in neighboring fields to control these weeds will also help resolve the problem.

Development of More Sustainable Weed Management Systems for Vegetable Crops and Strawberry

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Introduction

Vegetable weed control systems in California are complex systems that require multiple inputs such as fumigants, hand weeding, herbicides, and mechanical tillage to provide economically viable weed management. Numerous cultural practices also contribute to vegetable weed control systems such as crop rotation, organic amendments, preirrigation and sanitation. Most herbicides used in vegetable crops provide only partial control, and require multiple inputs to provide acceptable weed control. The expansion of organic vegetable production, as well as the need for conventional growers to reduce adverse environmental impacts, requires the development of more sustainable vegetable weed management programs. We are searching for sustainable weed vegetable management systems by enhancing existing practices used in vegetable crops, such as mechanical cultivation, preirrigation and weed removal, as well as cultural practices such as compost application and cover crop production.

Organic Amendments

Cover crops and compost are used primarily to improve soil quality (Wyland et al. 1996). But numerous effects of organic amendments on weed populations have been reported (Gallandt 1998; 1999). High organic matter has been associated with weed seed degradation in muck soils (Lewis, 1973). Increased organic matter content and high biological activity near the soil surface, due to reduced tillage, may favor weed seed degradation (Cardina et al. 1991; Kremer 1993). It is not known if the addition of organic inputs may be unfavorable to weeds.

Evaluations of the effects of organic amendments (cover crops and compost) versus no organic amendments, were conducted in a California vegetable field. Weed densities were monitored, and soil samples were taken to measure the effects of the treatments on weed seedbanks and microbial biomass over a 24-month period. We found indirect evidence that suggests relationships between organic amendments, weed population reductions and increases in soil microbial biomass: 1. Shepherd's-purse emergence and seedbank densities were lower where organic amendments were added compared to no organic amendments, 2. Microbial biomass was nearly always higher where organic amendments were added compared to where no organic amendments were used, 3. An inverse relationship between microbial biomass and burning nettle and shepherd's-purse emergence densities was found. These results suggest that organic matter addition may reduce weeds.

Machine-guided Precision Cultivators

Machine-guided cultivation has the potential to greatly increase the precision and speed of cultivation. Weed removal by tractor cultivation is among the more tedious and time consuming farming tasks, and the level of accuracy is highly dependent on operator skill (Slaughter et al. 1999). Machine-vision guidance takes the task of guiding the fine movements of the cultivator thus allowing for more rapid and accurate operation. A typical machine such as the Eco-Dan guidance uses a digital color camera that takes 25 pictures per second of the green plant row directly beneath it. These pictures are streamed to a computer where the row centerline is interpreted. As the row centerline shifts the computer signals, a control valve to move a hydraulic cylinder right or left to keep the implement in the correct working position over the row. The Eco-Dan guidance can differentiate between plants within the row and random weed patterns (Cline 2003).

Currently, it is common for growers to leave a 4-inch wide band uncultivated at each seedline, i.e., 80% of the bed is cultivated on a 40-inch wide bed with two seedlines (Haar and Fennimore 2003).

New precision cultivation using machine vision provides the opportunity for growers to cultivate as close as a 2-inch wide uncultivated band at each seedline (Israel Morales, American Farms and Niels Andrews, Local Positioning Systems, personal communication). The potential impacts of precision cultivation on broccoli and lettuce production are: 1. Less herbicide will be needed if herbicide band widths can be narrowed, 2. If cultivator operators can drive faster, then cultivation labor efficiency may increase, 3. If precision cultivators will allow closer cultivation and can remove more weeds, then hand weeding operations may be more efficient. However, the potential economic benefits of close cultivation on herbicide band-width, handweeding time, and vegetable yield and quality has not been documented. This technology could also benefit organic vegetable growers as well by allowing for faster more accurate cultivation as well as a narrower uncultivated band that will leave fewer weeds for hand weeding crews to remove. In cooperation with an equipment dealer and several growers, we are currently evaluating the use of machine vision to increase cultivation efficiency.

Weed removal with preirrigation and shallow tillage

Pre-plant irrigation of dry soil, followed by an interval of one or two weeks to partially dry the soil, then followed by shallow tillage to create a smooth planting bed, is essential during field preparation for small seeded crops. The field is irrigated usually by furrow or sprinkler irrigation, allowed to dry long enough to permit tillage, and then tilled to prepare a smooth planting bed. This practice kills many weeds that emerge during the interval between irrigation and shallow tillage. However, little has been done to quantify the value of this cultural practice in vegetable weed management programs. We evaluated whether pre-irrigation and shallow tillage can control a large portion of the germinable weed seedbanks and thus reduce dependence on herbicides. Studies were conducted in Salinas, CA to evaluate the weed control efficacy of treatments that were watered by furrow and sprinkler irrigations applied one or two weeks prior to planting, compared to control plots that did not receive pre-plant irrigation. Early season weed density, time required for hand weeding and final yield were recorded. Most pre-irrigation treatments consistently reduced weed densities and hand weeding inputs. Up to a 50% reduction in the time needed for early season hand weeding was observed. Preirrigation, in combination with reduced rates of pronamide, provided sufficient weed control in lettuce, suggesting that pre-irrigation could reduce the reliance on herbicides. Pre-irrigation with a sufficient time interval prior to planting, is an effective method for early season weed control in vegetable plantings for both organic and conventional production.

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Evaluation of Alternative Herbicides for Landscape Weed Management

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Schools and parks are faced with the problem of controlling weeds on their grounds but are also under public pressure to reduce the use of synthetic herbicides. Many landscapers feel that alternatives such as hand weeding or mowing are not as cost or time efficient. In the past 3 years more attention has been direct towards herbicides derived from exempt or GRAS materials. These products may be listed as organic and most have a toxicity rating of "Caution." Use of these types of products may have better public acceptance

Six of these "least-toxic" (LT) products were evaluated for herbicidal efficacy under landscape/turf conditions and compared to weed control obtained using the industry standard, glyphosate (Table 1). Products tested included Eco-Exempt, Matran 2, AllDown, Burnout II, and Weed Zap. These herbicides list their active ingredient as eugenol, clove oil, or cinnamon oil. Both cinnamon oil and clove oil have eugenol as a major component. A citrus molasses-based product, Cimonex was also tested. Roundup Pro was used as the industry standard. All of the LT herbicides tested have contact activity while glyphosate is a systemic herbicide. Tests were conducted at a turf section in a park in Santa Barbara County using a randomized complete block design with four replications. A second treatment was applied 6 days after the first treatment. Vegetation was primarily St. Augustinegrass and Bermudagrass mixed with birdsfoot trefoil.

Table 1. Materials evaluated for weed control and application rates.

Herbicide	Rate*
Eco-Exempt	5:1
Matran 2	7.5 gal/A (~14:1)
Cimonex	3:1 FB 1:1
AllDown	RTU
Burnout II	2:1
Weed Zap	4 oz/gal (~32:1)
Roundup Pro	1.5% (~66:1)

*The rate selected of the LT herbicides was the highest rate recommended per the product label.

Results

None of the LT herbicides were as effective as Roundup Pro (100% control of grasses with 1 or 2 applications) although AllDown and Burnout II provided 51 and 46% control of grasses respectively with 2 applications even 5 weeks after the second application. The others provided 4-30% control (Table 2). Overall, the eugenol base products provided quick burndown of the plants similar to that of diquat (Reward) but were not as effective as Roundup Pro for longer-term control.

Table 2. Percent control of weeds by tested herbicides applied one or two times. Application dates are: June 8, 2004 and June 14, 2004.

Treatment	**6DAT**		**Herbicides applied one time (41DAT)**			**Herbicides reapplied 6 days after first application (35DAT 2nd application)**		
	Grasses	**BL***	**Overall**	**Grasses**	**BL**	**Overall**	**Grasses**	**BL**
UTC	**0**	**0**	**0**	0	0	0	0	0
Roundup Pro	**100**	**54**	**99**	99	100	99	99	100
EcoExempt	**98**	**84**	**30**	23	11	30	30	11
Matran	**96**	**86**	**14**	13	10	15	16	45
Cimonex	**0**	**29**	**6**	6	4	6	6	1
AllDown	**97**	**73**	**29**	28	14	39	51	84
Burnout II	**98**	**93**	**36**	30	34	51	46	65
WeedZap	**40**	**26**	**5**	4	0	5	4	0

***BL="Broadleaf" plants**

Discussion

Roundup Pro 1X is most effective for long-term and cost effective control (Table 3) in established areas. Where Roundup Pro is not an option, AllDown and BurnOut provide good control with 2 applications but cost is ~30X higher than Roundup or 15X higher than Reward (material only). However, there may be some convenience savings where exempt materials are used because use of these products do not require posting at some sites, such as schools.

Table 3. Cost per acre of formulated product. Costs were determined from retailers on mail-order sites.

Product	**$/A**
Roundup Pro	81
EcoExempt	1843
Matran	608
Cimonex	n/a
AllDown	1733
Burnout II	1216
WeedZap	n/a
Reward	83

In this test, we compared the LT products to glyphosate since that is the product of choice for many landscapers. However, in order to make a proper comparison of these products, one should compare them to similar burndown contact herbicides such as diquat or glufosinate (Finale).

Finally, while many of the products were a combination of botanically based oils including eugenol and cinnamon oil (Table 4), it is likely that the principle component imparting plant injury is eugenol. Tworkoski (2002)1 determined that essential oil of cinnamon had high herbicidal activity, and eugenol (2-methoxy-4-[2-propenyl]phenol) was determined to be this oil's major component (84%, v/v). Dandelion leaf disk and whole-plant assays verified that eugenol was the active ingredient in the essential oil of cinnamon. The more effective products had a final percentage of about 3-4% eugenol when active ingredients were converted to eugenol equivalent (Table 5).

Table 4. Active ingredients of Least Toxic products evaluated.

Eco-Exempt HC

2 phenethyl propionate	21.49%
Eugenol (clove oil)	21.4%
Inerts: Water and lecithin	

Matran 2

Clove oil	46%
Water, lecithin	54%

Cimonex

Citrus unrefined molasses containing unspecified amounts of citrus peel liquor

AllDown

Citric acid	5%
Garlic	0.2%
Vinegar, water	94.80%

Burn Out II

Clove oil	12%
Sodium lauryl sulfate	8%
Other: Vinegar, lecithin, water, citric acid, mineral oil	80%

Weed Zap

Cinnamon oil	30%
Inerts: Lactose, vinegar and water	70%

Table 5. Percentage eugenol in herbicide concentrate and applied formulation.

	Percent solution applied	Percent eugenol in concentate	Final percent eugenol (in spray solution)
Eco-Exempt	**16.70**	**21.4**	**3.57**
Matran 2	**6.70**	**46**	**3.08**
Burnout II	**33.00**	**12**	**3.96**
Weed Zap	**3.00**	**25**	**0.75**

[1]Tworkoski, T. 2002. Herbicide effects of essential oils. Weed Science 50:425-431.

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Environmentally Friendly Almond Pest Management

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Currently there are approximately 550,000 bearing acres of almonds in California, producing more than 80% of the world's supply. Several arthropod pests feed on the fruit and foliage of almond trees, affecting kernel quality and yield. Historically, growers have managed these pests with dormant and in-season sprays of organophosphate and pyrethroid insecticides. Recently, these sprays have been implicated in the contamination of surface and ground water throughout the state. There are also concerns over farm worker exposure as well as the development of resistance to these materials by targeted pests. These concerns, coupled with the regulatory threat of the Food Quality Protection Act (FQPA) are fueling efforts to find reduced risk alternatives to "conventional" insecticides.

In 1999, the University of California Cooperative Extension, the Almond Board of California, the Community Alliance with Family Farmers, and the Almond Hullers and Shellers Association joined together to form the Almond Pest Management Alliance (PMA), funded by a $500,000 grant from the California Department of Pesticide Regulation. Three field trials designed to develop and demonstrate alternatives to broadly toxic insecticides were set up in the major almond producing areas of the state. Treatments representing "conventional" and various "reduced environmental risk" programs were imposed in large, replicated field trials over a five-year period. Trial results proved that if monitoring and decision-making protocols are followed, the number of pesticide applications can be substantially reduced and "reduced risk" materials can be used without significant increased risk to the crop. However, an economic analysis showed that pest management programs utilizing "reduced risk" materials are more expensive. In addition, intensive monitoring adds even more cost. However, if monitoring indicates sprays are not necessary, money can be saved.

Thirty workshops were held during the five-year project to share trial results and demonstrate monitoring techniques to local growers and PCAs. These workshops resulted in approximately 3500 contacts with members of the almond growing community. During the period of this project, California almond growers reduced their use of chlorpyrifos and diazinon by 45.3% and 44.7%, respectively.

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Session IV

Nutrient Management

Session Chairs:

Tim Hartz, UCCE-UC Davis

Joe Fabry, Fabry Ag. Consulting

Managing Phosphorus and Potassium for Maximum Alfalfa Yield and Quality

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Introduction

Many factors are involved in producing a high-quality alfalfa crop. Although some factors (like rainfall and temperature) cannot be controlled, many other critical components of the production system can be carefully managed. High yields require maintenance of an adequate nutrient supply to meet the needs of the rapidly growing crop. As the demand for high-quality and high-yielding hay increases, closer examination of the role of proper plant nutrition is needed.

It is not always simple to determine the “correct” amount of fertilizer to add to alfalfa. In most regions, alfalfa growth begins in the early spring, continues through the summer and into the late fall. This very long growing season places a continuous demand on the soil nutrient supply to provide essential elements for many months under widely ranging environmental conditions. Due to this wide range of growing conditions, only general guidelines are presented here, and they must be adapted to meet local needs. It should also be noted that many experiments on alfalfa fertilization were done at yield levels low by present-day standards. While these experimental results are helpful in establishing trends, they can be misleading when making precise fertilizer recommendations for modern alfalfa growers.

An essential component of profitable alfalfa production is achieving high yields. Lower costs of production (per ton), improved efficiency, and maximum profits are usually obtained when near maximum yields are grown. High-yielding alfalfa removes large amounts of nutrients from the field in each cutting. On average, alfalfa removes 50 lb N/ton, 13 lb P_2O_5/ton, and 60 lb K_2O/ton. Rapidly declining soil concentrations are regularly measured in conditions where nutrients are removed from the field in alfalfa hay, but low replacement quantities do not match crop removal (e.g. Cihacek, 1993).

Phosphorus and K fertilization are essential for alfalfa production and are the most common nutrient inputs for this crop. These nutrients are involved in many essential metabolic roles within the plant, and deficiencies result in slow growth, suppressed yields, and lost income. This brief review covers some of the recent work regarding P and K fertilizer management for achieving high alfalfa yields.

Phosphorus for Alfalfa Nutrition

Phosphorus is involved in a variety of essential reactions within the plant. Higher P concentrations are generally measured in the meristematic regions of actively growing plants. Since P is mobile within the plant, it will translocate from older to younger tissue as required.

Most of the P entering the plant rapidly becomes converted into organic compounds, where it becomes involved in a variety of essential reactions. For example, P in alfalfa is essential for formation of nucleic acids, phospholipids, and ATP; and associated with functions such as photosynthesis, protein formation, and nitrogenase activity. Low plant P frequently results in high leaf starch concentrations, which is thought to decrease leaf photosynthetic rates. Reduced leaf expansion (especially the epidermal cells) is also seen in low-P plants. Alfalfa growing with sub-optimal P concentrations typically has high root starch and root protein concentrations- however the plants are not able to utilize these organic reserves after cutting and cannot quickly regrow (Li et al., 1998). Phytic acid, a major storage form of organic P commonly found in seeds, also accumulates in alfalfa roots and crowns. Campbell et al. (1991) estimated that phytic acid P accounted for 10 to 15% of total alfalfa root and crown P.

In addition to direct nutritional benefits, other positive plant responses come from maintaining adequate P supplies. For example, Azcon et al. (1988) reported that in addition to increased alfalfa yields and tissue concentrations, P fertilization also resulted in an increased number of rhizobia nodules, larger nodule size, and greater N fixation. The stimulatory effects of added P on N fixation were clearly shown with tropical alfalfa (Table 1). Numerous other studies have documented the increase in water-use efficiency in properly fertilized crops compared with alfalfa lacking in nutrients such as P or K.

There have been frequent reports that P or K nutrition have been found to improve plant disease tolerance or resistance. This nutrient response could be due to the influence of P and K on plant growth and vigor, leading to improved disease resistance or tolerance, or possibly due to its direct influence on pathogen activity in the soil prior to infection. While these responses are frequently observed, the complex interaction of pathogen, environment, and time make it difficult to generalize regarding disease responses from added nutrients.

Table 1. Phosphorus additions increase nodule weight, size, and N content in alfalfa (Gates, 1974).

	P Addition (kg P/ha)				
	0	31	62	125	250
	mg				
Nodule dry weight	0.13	0.44	1.06	3.31	8.47
Weight/nodule	13	33	28	60	57
N content	0.01	0.03	0.07	0.15	0.65

Phosphorus Fertilizer Management for Alfalfa Production

Soils vary in their ability to supply P and visible nutrient deficiency symptoms are generally hard to detect, unless the deficiency becomes quite severe. Therefore, soil testing is generally the most effective way of predicting the potentially available nutrient supply. The recommended procedure for soil sampling and laboratory analysis varies in different parts of the country based on regional differences, so local advice should be obtained on how to best do this. Tissue testing for P is generally recommended for crop diagnostic monitoring after the alfalfa is established.

Only a portion of applied P is available to the crop during the year of application, since it becomes involved in many soil reactions that tend to reduce its solubility (Rehm and Sorensen, 1974). Fertilizer P is relatively immobile in soil when applied at normal agronomic rates, so initial P applications are most effectively placed below the soil surface in order to improve uptake by roots. Banding fertilizer P generally optimizes the P recovery, especially where the soil is very deficient and in non-irrigated conditions where moisture limitations may keep roots from utilizing surface-applied P (Malhi et al., 2001). However, surface banding P fertilizer onto established irrigated alfalfa stands may not offer yield advantages over broadcast P applications (Reid et al., 2004).

Fertilizer guides generally recommend that P be applied prior to establishing the crop since an adequate supply of P is critical for rapid stand development. Adequate P is essential for development of strong root systems and fertilization benefits are most apparent in infertile soils and where cool weather restricts nutrient uptake. A beneficial response to added P will only occur when the roots are able to access it- which includes having sufficient soil moisture and other essential nutrients present in adequate supply.

On established stands, fall or winter applications of P are generally preferred since crop responses are often not seen until 2 to 3 months after application. Avoid applications when the soil is soft and physical damage to plant crowns is more likely to occur from field machinery. James et al. (1995) showed that soil P fertility for alfalfa can be maintained by either small annual applications or larger single applications for a multi-year crop rotation. Surface P applications are apparently effective due to the zone of high root activity near the surface and the uptake of P directly by the crown. Adequate soil moisture is essential in order for the plant to recover these surface-applied nutrients.

Many sources of fertilizer P are successfully used for alfalfa production- including both solid and liquid forms. A number of comparisons have shown that most P fertilizer sources are equivalent, when used properly (e.g. Cihacek, 1993; Reid et al, 2004). The selection of a specific P fertilizer form is generally based on local availability, ease of application, and the cost per unit of nutrient. Application of liquid P sources with irrigation water is an effective way of delivering frequent doses of nutrients, but care should be taken if applying P through sprinkler systems to avoid precipitation and plugging of the pipes. Ottman et al. (2000) found no consistent yield or quality differences between liquid or solid P fertilizers. They also reported that solution P fertilizer (10-34-0) was equally effective whether sprayed on the surface of the soil or added to the crop with the irrigation water.

Animal manures can be a good source of nutrients, but application to alfalfa does not take full advantage of the added N and may make weeds more difficult to control. Manure applications may burn leaves, reducing hay yield and quality. Field operations associated with manure application may also damage plant crowns and shorten the stand life.

Phosphorus fertilization is an essential component of alfalfa production. A soil test should be taken and the nutrient recommendation followed prior to planting to help improve seedling establishment and promote overall early vigor and competitiveness. The soil nutrient status should be monitored with tissue testing and the large amounts of P removed in high-yielding crops must be replaced when the soil P supply can not meet the plant demand. A variety of P sources can be successfully used and the application method should be chosen to maximize the efficiency of the applied fertilizer. Failure to monitor and replace the nutrients removed in the harvested hay will lead to losses of yield, plant stand, and profit.

Potassium Fertilizer Management for Alfalfa Production

More potassium is removed in harvested alfalfa than any other soil nutrient (50 to 60 lbs K_2O/ton of hay). Potassium deficiency is a relatively recent occurrence in many Western soils. For example, many Western fertilizer guides from the 1950's declared that only few K deficiencies existed due to high native levels of soil K and the presence of K in irrigation water. However, a long history of high-yield alfalfa production has depleted native soil K levels in many places and regular soil testing is now recommended and fertilization suggested where needed to replace the harvested K.

Potassium has many critical roles in plant growth and development. In addition to the well-recognized role of K in stomatal regulation and photosynthate transport, K also has an important role in enhancing N_2 fixation in alfalfa (e.g. Collins and Duke, 1981). Adequate K also helps to reduce grass and weed invasion and improve stand persistence.

Alfalfa has lower root density than most grasses and generally a deeper rooting zone where soil moisture is available. Despite this deep root system, Peterson et al. (1983) reported that alfalfa absorbed K most heavily from the surface soil volume, compared with the Ap and deeper horizons. This finding supports the efficiency of the common practice of topdressing K fertilizer onto existing stands of alfalfa when needed.

Alfalfa can accumulate greater amounts of K than are required for the level of hay production- called luxury consumption. The range between crop deficiency (and resulting yield loss) and slight luxury consumption may be difficult to precisely delineate and may also vary throughout the growing season based on environmental factors. Since maximum profitability is generally achieved by obtaining high efficiency and high yields, it is not beneficial for a farmer to grow hay with insufficient nutrient inputs.

Ruminant animals have a higher K requirement than non-ruminants. Potassium is essential for rumen microorganisms. The most commonly observed effect of suboptimal K in the feed of ruminants is decreased feed intake. Lactating dairy cows, especially high-producing cows, require the highest levels of dietary K. Under high heat stress, their optimal level of dietary K can be as high as 1.9%, but the normal NRC recommendation is 1% of the dietary dry matter. Less dietary K (0.65%) is suggested for dry cows, calves, and heifers. During the last several weeks before calving, excessive K in the dry cow diet can increase the occurrence of milk fever and retained placentas- leading to reduced milk production during the subsequent lactation, so dietary high K should be avoided during this time.

There are several suitable K sources for alfalfa fertilization- most commonly KCl, K_2SO_4, and K_2SO_4-$MgSO_4$ (potassium & magnesium sulfate). The selection of a specific K source is largely based on the need for the accompanying nutrients (such as S and Mg) and price. Once soil K concentrations are adequate, moderate rates of K applied annually may be sufficient to maintain high levels of production.

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Perchlorate Content in Water and Vegetable Crops

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A number of animal and human studies have shown that exposure to perchlorate disrupts thyroid hormone regulation by competing with iodine (USEPA, 2002). The principal hormones involved are thyroxine (T4) and triiodothyromine (T3), both iodine containing amino acids. Perchlorate has been discovered in surface and ground water supplies throughout the United States. There is concern that these perchlorate tainted water sources may represent a health risk both as sources of drinking water to humans and irrigation water to food crops. A survey of 367 groundwater wells in 17 states found perchlorate in only 9 wells less than 4 to 7 ppb (Gullick et al., 2001). Perchlorate contamination of the Colorado River is well documented and the concentration at Lake Mead had been measured at 14 ppb. This contamination is introduced into Lake Mead through a spill by a perchlorate salt manufacturing plant on the Las Vegas Wash. It has been reported that the Colorado River below Lake Mead has concentrations ranging from 5 to 9 ppb (DHS, 2000).

Some plant species have been shown to absorb and accumulate perchlorate from soil and irrigation water (Urbansky et al., 2000; Ellington et al., 2001; Nzengung et al., 1999; Nzengung and Wang, 2000). Accumulation in crops where leaves are consumed is a major concern. Hutchinson et al., (2000) found perchlorate accumulated in lettuce during early growth stages under conditions in the glasshouse. In a more recent glasshouse experiment, Yu et al., (2003) evaluated perchlorate uptake by lettuce, cucumber, and soybean in sand culture. Perchlorate accumulation was higher in lettuce compared to cucumber and soybeans. The accumulation ratio of perchlorate in lettuce at the end of six weeks exceeded 300.

We conducted a survey to determine if perchlorate accumulates in vegetable crops in the lower Colorado regions of Arizona and California irrigated with Colorado River water. Crops sampled include iceberg, romaine, and leaf lettuce (*Lactuca sativa* L.), broccoli (*Brassica oleracea* L. var *italica*), cauliflower (*Brassica oleracea* L. var. *botrytis*), cantaloupes (*Cucumis melo* L.), watermelons (*Citrullus lanatus* L.), carrots (*Daucus carota* L.), onions (*Allium cepa* L.) peppers (*Capsicum annum* L.), sweet corn (*Zea Mays* L.), tomatoes (*Lycoperscion esculentum* L.) and other miscellaneous vegetables. Samples were prepared by freeze-drying, grinding, hot-water extraction and multiple filtrations and analyzed for perchlorate by ion chromatography.

Perchlorate was found to be below detection limits for approximately 75% of the vegetable specimens collected. For those vegetable specimens with detectable levels of perchlorate, all values were below 100 µg/kg on a fresh weight basis.

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Developing a Better System for Assessing the Nutritional Status of Peach and Nectarine Trees

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Introduction

In this modern era of increasing concern over environmental stewardship, every fertilization event needs to be carefully evaluated and fully justified. Excess nutrients can easily escape from the orchard and become environmental pollutants or even remain in the orchard as soil contaminants. It is important to apply fertilizers only when they are needed for optimum production and to make sure they are not applied in excess. Having a method for assessing nutritional status of trees is a critical tool to help guide this process.

The Standard Approach

The established method for nutrient sampling of fruit trees is a mid summer leaf analysis (Shear and Faust, 1980; Robinson et al., 1997). This procedure was introduced about 50 years ago (Batjer and Westwood, 1958) and has been widely applied throughout the world (Leece et al., 1971 and references cited therein). Apparently, the rationale for this timing was based on the observation that leaf nutrient levels remain relatively stable during the summer period, thus providing a wide window for sampling. Unfortunately, the timing is not ideal for many cultural practices. In general, it is too late to have any impact on fruit and shoot growth for that season. Also, once leaves have become more mature, they tend to not take up foliar nutrients as well as young tender leaves in the spring. Finally, soil applications of fertilizers too late in the summer present an increased risk of minimal uptake into the tree and thus a greater risk of environmental contamination. In short, mid summer is not the time of year when fruit growers are thinking about and implementing nutritional programs.

In order to develop an effective and useful sampling procedure for fruit trees the following guidelines should be considered:

1. The sampled tissue should correlate with growth and productivity processes in the tree.
2. The timing of the procedure should be such that immediate corrective measures could be applied if a deficiency is detected.
3. The results should be reproducible from one orchard, variety, season and growing region to another.
4. The sampled tissue should be indicative of the whole tree nutritional status.
5. The test should reveal both deficiencies and excesses for each nutrient.
6. The procedure should be relatively simple and convenient to implement.

The standard method of mid summer leaf analysis generally performs well on guidelines 3-6, but not as well on the first two (problems with #2 are discussed above). Much of the early work that was conducted to establish this procedure was based on leaf symptoms rather than yield parameters. However, leaf symptoms for some nutrients often appear after a reduction in productivity has already occurred. For other nutrients, leaf symptoms can show up without any noticeable effects on growth or yield. Therefore, the deficiency thresholds that have been developed may not relate as well as they should to productivity. In order for a new procedure to be an improvement, it would need to combine the reproducibility, usefulness and simplicity of mid summer leaf sampling with better timing and closer correlation with yield parameters.

A Better Approach

As trees first start to grow in the spring, growers are very concerned about the health and potential size and quality of the crop. Many processes affecting yield and fruit quality happen in the early spring. Flowering, fruit set, fruit cell division (a large factor in potential fruit size), and early shoot growth all occur during the first 30 to 40 days after trees start to grow. Therefore, a sampling procedure during this time would be strategically more useful. There are several tissues that could be sampled for nutrient analysis. These include dormant roots, dormant shoots, flowers and early leaves.

A large experiment with peach and nectarine trees growing in sand culture was initiated in 1999 (Johnson et al., 2003). By applying different combinations of fertilizers, trees with widely varying nutrient contents have been achieved. These trees have been very useful for analyzing the various methods of sampling and comparing them to the standard mid summer leaf procedure. For all the major nutrients (N, P, K, S, Ca, Mg, B, Zn, Mn, Fe and Cu) a 2 to 3 fold range in leaf nutrients has been measured among different trees. In the lower range most have shown some indication of deficiency. The tissues sampled in late winter and early spring likewise showed a similar range of nutrient levels in most cases. However, certain tissues appeared to be more consistent than others. For example, flowers had very high concentrations of N, P and S even in those trees that showed signs of being deficient in these elements. Early leaves showed similar trends. On the other hand, dormant roots had very low concentrations of Ca and Mg even in trees that had been heavily fertilized with these nutrients and had high leaf values. Therefore it seems unlikely that these tissues would be reliable for identifying deficiencies and excesses of all major nutrients. However, dormant shoot sampling has so far proved to be a fairly reliable procedure for all the nutrients. Furthermore, it is a very simple tissue to collect (especially compared to root sampling) and can be sampled over a long time period (in contrast to flower sampling). Therefore, it appears to be a strong candidate for an improved method of assessing peach and nectarine tree nutritional status.

Dormant Shoot Sampling

The next step to establishing dormant shoot sampling as a reliable nutrient assessment procedure is to correlate nutrient concentrations with productivity processes occurring in the spring (guideline #1). This information can be used to establish deficiency thresholds for each nutrient. Several examples will be illustrated here.

Boron has long been known to have an effect on fruit set in many plants (Shorrocks, 1997). Such was certainly true for both Zee Lady peach and Grand Pearl nectarine trees growing in the sand tank experiment. Figure 1 illustrates the relationship with dormant shoot B in peach for 2003 and 2004. Based on this relationship, a deficiency threshold of about 12 to 15 ppm B could be established. A similar relationship with the same threshold was observed for the nectarine (data not shown).

Phosphorus deficiency symptoms were quite prominent in the sand tank trees in 2004. One striking symptom was fruit cracking in the nectarine trees, affecting more than 80% of the fruit on some trees. There was a good correlation with dormant shoot P (Figure 2) and a secondary relationship with shoot Zn. Deficiency thresholds of about 0.12% P and 20 ppm Zn could be extrapolated from this relationship. Additional relationships between shoot P and fruit shape or premature fruit drop (data not shown) supported the same deficiency threshold.

Besides the effect on fruit cracking, dormant shoot Zn also correlated reasonably well with leaf symptoms in the spring (Figure 3). Once again a deficiency threshold of about 20 ppm Zn could be deduced from the relationship.

By analyzing other yield and fruit quality components, such as flower density, vegetative growth, fruit size and fruit defects, deficiency thresholds can be established for all the other nutrients as well. Often the relationships are not quite as strong as those illustrated above, but field experience and trial and error will help refine those over time.

Future Directions

The final step is to test the procedure in numerous locations with different varieties, rootstocks, soil types and climatic conditions to see how reliable and reproducible it is (Guideline #3). Refinement in the procedure may also be needed in case there is an effect of timing during the dormant season or location within the tree. Contamination from foliar Zn, Cu and other micronutrient sprays may also create complications.

Dormant shoot sampling to assess peach and nectarine tree nutritional status holds great promise as a useful tool to help guide orchard fertilization practices. It seems to have all the characteristics of an effective sampling procedure. Perhaps, over time, it could develop into a standard practice for fruit trees.

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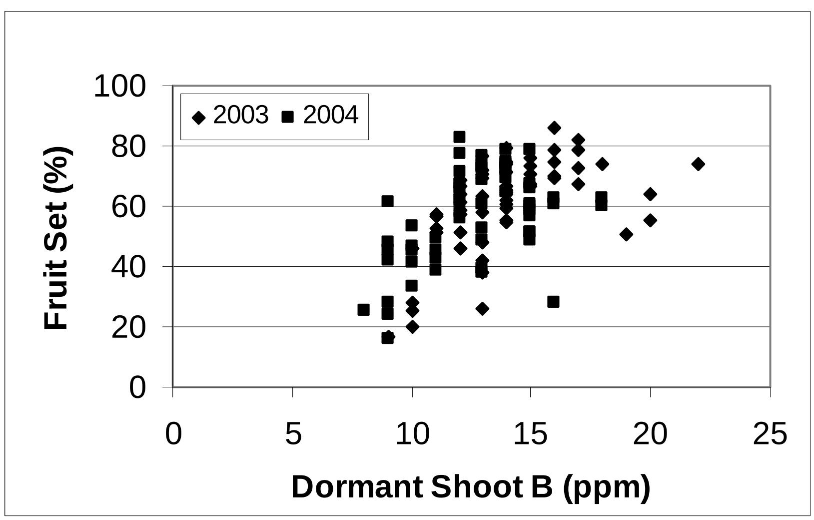

Figure 1. The relationship between fruit set and dormant shoot B for Zee Lady peach in the sand tank experiment in 2003 and 2004.

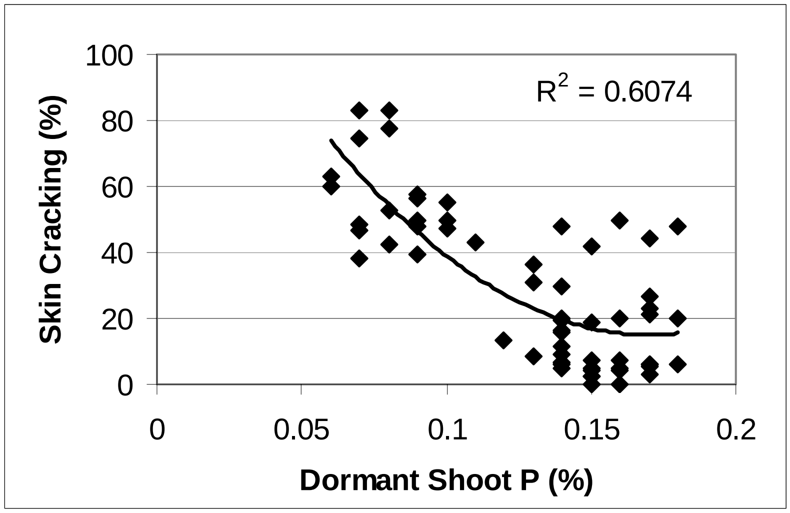

Figure 2. The relationship between Grand Pearl nectarine fruit cracking and dormant shoot P in the sand tank experiment in 2004.

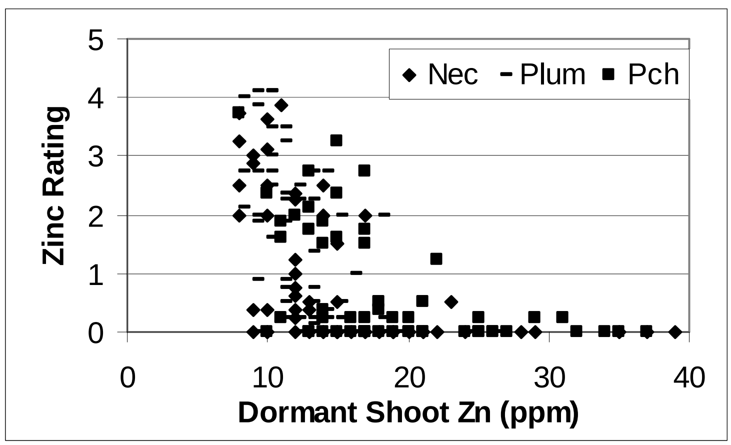

Figure 3. The relationship between Zn deficiency symptoms (0 = none, 5 = severe) and dormant shoot Zn for Zee Lady peach, Grand Pearl nectarine and Fortune plum in the sand tank experiment in 2004.

Evaluation of Polyacrylamide (PAM) for reducing sediment and nutrient concentration in tail water from Central Coast vegetable fields

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Introduction

State and federal water quality regulations, such as the Conditional Waiver for Agricultural Discharge and proposed Total Maximum Daily Loads (TMDL) for nutrients and sediments, will require that Central Coast growers implement best management practices that minimize impairments to surface and ground water quality. Growers, who produce vegetables and row crops on soils susceptible to erosion, may have a difficult challenge in reducing sediment and nutrient levels in irrigation run-off. Though many producers are using sediment basins and drip irrigation to minimize run-off and capture sediments, these practices are costly and may not fully achieve water quality targets. Treating soil with polyacrylamide (PAM), a large polymer chain molecule (10-15 Mg/mole), could potentially reduce sediments and nutrients lost from furrow and sprinkler irrigated vegetable fields by maintaining infiltration and stabilizing soil aggregates. Despite documented benefits of PAM for erosion control in other areas of the country (Bahr et al. 1996, Lentz and Sojka 1996, Sojka et al. 2000, Trout et al. 1995), PAM has not been used in vegetable production along the Central Coast. Additionally, few studies have documented water quality benefits from using PAM applied through solid-set, impact sprinklers, which are widely used by growers on the Central Coast. Our initial trials evaluating PAM used in sprinkler and furrow systems, demonstrated significant reductions in sediment and nutrient concentration in irrigation run-off.

Procedures

We conducted column and field studies to quantify the effect of PAM on infiltration rate, run off, and concentration of sediment and nutrients (ortho and total P, total N, and NO_3) in run-off from sprinkler and furrow irrigation systems. Because PAM has not been shown to be beneficial on all soil types and water qualities, the column studies screened a larger range of soil types and water compositions than could be accomplished with field studies. Field studies evaluated the effect of PAM on infiltration rate using a recirculating infiltrometer. In addition, trials were conducted in cool season vegetable fields to measure the effect of PAM on runoff, sediment and nutrient loss as well as the effect on yield.

<u>Column experiments</u> Column studies were conducted to evaluate the effects of polyacrylamide (Amber 1200D[5] and Soilfoc 100D[2]) on infiltration in 10 soils collected from agricultural fields in Monterey, San Benito, and Santa Cruz counties. Soil samples were sieved to pass through a 2 mm screen and packed into columns with a 7-cm diameter and a 5-cm height to a bulk density ranging from 1.1 to 1.5 g cc^{-1}. A constant head burette was used to maintain a 2.5-cm (1 inch) head of water above the surface of the soil. Pressure transducers and dataloggers were used to monitor the rate that water was depleted from the burettes. Experiments evaluated the effect of polyacrylamide products, concentration, and interaction with water quality (total dissolved salts, sodium adsorption ratio) on infiltration rate.

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[5] formerly Superfloc A-836, Amber Chem. Inc; [2] Soilfloc 100D, Hydrosorb, Inc.

Recirculating infiltrometer experiments Infiltration rates of PAM and untreated control treatments were compared in the furrows of 6 commercial vegetable fields using a recirculating infiltrometer. Water, treated with 10 ppm concentration of Amber 1200D was first added to a 20 ft-length of furrow. The water reaching the end of the furrow was recirculated to the head using a bilge pump. Untreated water was added from a tank to the head of the furrow to maintain a constant depth of water. Infiltration was estimated by measuring the rate that the tank emptied. Composite water samples were taken at the tail-end of the furrow for chemical analyses.

Field trials Polyacrylamide and untreated control treatments were compared in replicated trials, conducted in commercial fields planted with romaine lettuce, iceberg head lettuce and broccoli. Trials followed a randomized complete block design with 4 replications. Polyacrylamide (Amber 1200D) was injected into the irrigation water to achieve a 5 ppm concentration for sprinkler and furrow irrigated trials. For the sprinkler trials, PAM was applied during the first 30 minutes of the irrigation set and again when run-off accumulated in the furrows until the end of the irrigation set. Application rates of PAM varied from 0.5 to 0.75 lb/acre per irrigation. For the furrow trial, PAM was injected until the water reached the end of the plots. Plots measured at least 100 ft in length and 80 inches in width. Run-off measurements and water samples were collected during 2 to 3 irrigations per trial. A sump at the lower end of the plots collected run-off from the sprinkler trials. Run-off was measured and sampled using equipment constructed from a bilge pump, float switch, and residential flow meter. Weirs were used to measure run-off in the furrow trial and composite samples were manually collected. Box yield and head size were evaluated at harvest in 4 of the 6 trials.

Results

Column experiments

PAM applied continuously in the infiltration water at concentrations greater than 10 ppm decreased the final infiltration rate of all soils tested (Table 1). The greatest decrease in infiltration occurred in the Oceano loamy sand. SoilFloc 100D decreased the final infiltration rate more than Amber 1200D and the highest concentration of PAM (20 ppm) decreased infiltration more than the lowest concentration (10 ppm). The effect of PAM on infiltration was dependent on the EC and the SAR of the applied water. In 4 soil types tested, increasing the EC of water treated with a 10 ppm concentration of Amber 1200 PAM, increased infiltration. Increasing the SAR of water treated with a 10 ppm concentration of PAM, decreased infiltration (Table 2). These results suggest that the ratio of sodium to calcium and magnesium in the water affects the chemical and/or physical properties of polyacrylamide. Relative viscosity measurements, conducted using columns packed with a standard sand media, demonstrated that the viscosity of the applied water increased as the concentration of PAM increased. The effect of PAM on viscosity may offset the ability of PAM to increase infiltration though improved aggregate structure. Pre-treating the surface of the soil with water containing PAM, rather than applying water with PAM continuously, maximized the final infiltration rate relative to the untreated control. The reduction in infiltration was minimized as the pretreatment volume was decreased and the concentration of PAM was decreased.

Recirculating infiltrometer trials

PAM had no significant effect on infiltration at 4 of 6 sites evaluated, but PAM increased the final infiltration rate at one site and decreased the infiltration rate at another (Table 3). Turbidity and total suspended solids were significantly reduced in the PAM treated water (Table 3). Overall, the PAM treatment reduced suspended solids by 85% compared to the untreated control. Additionally, soluble and total P, and total nitrogen were reduced in the PAM treated water. PAM had no effect on nitrate or salt levels in the run-off.

Sprinkler field trials

PAM applied through the sprinkler system was able to significantly reduce the turbidity and the suspended solids in the tail-water (Table 4). Similar to the results obtained with the recirculation infiltrometer trials, PAM reduced soluble and total P and total N in the run-off, but had no significant effect on NO_3-N. Total sediment loss was reduced by 95% at trial 1. The PAM applications had no significant effect on romaine carton yields and head size.

Acknowledgements

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Table 1. The effect of polyacrylamide concentration on the infiltration rate of soils from Monterey, San Benito, and Santa Cruz Counties.

Treatment[1]	n	Placentia sandy loam	Clear Lake clay	Mocho silt loam	Salinas clay loam	Chualar loam	Oceano loamy sand	FHAX complex [2]	Cropley silty clay	Sorrento silty clay loam	Sorrento silt loam
		final infiltration rate (mm/hr)									
Control	6	9.03	1.47	46.46	3.91	39.94	129.05	17.09	2.29	2.94	5.32
Amber 1200 (10 ppm)	6	8.65	1.26	33.96	3.34	27.53	39.35	11.90	2.03	2.24	5.10
Amber 1200 (20 ppm)	6	6.43	1.24	23.83	2.95	18.88	20.64	6.77	1.54	1.78	3.09
SoilFloc (10 ppm)	6	6.64	0.85	21.40	2.57	21.22	23.24	7.49	1.45	1.75	2.47
SoilFloc (20 ppm)	6	3.71	0.52	12.25	0.96	10.16	14.33	3.92	0.64	0.85	1.01
Average		6.90	1.07	27.58	2.75	23.54	45.32	9.43	0.18	1.91	3.40
$LSD_{0.05}$		1.95	0.21	1.85	0.50	3.46	21.81	1.40	1.59	0.13	0.72
P > F[3]		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
CV (%)		10.9	16.4	5.5	14.9	12.0	39.3	12.2	9.2	5.7	17.4

1. water quality: EC = 1 dS/m, SAR = 2, pH = 6.2
2. Fluvaquentic Haploxerolls-Aquic Xerofluvents complex (loam).
3. probability of obtaining (by chance alone) an F statistic greater than the computed F value.

Table 2. Effect of SAR (sodium adsorption ratio) on infiltration rate in soils from Monterey Counties using water treated with polyacrylamide.

PAM	SAR[1]	n	Placentia sandy loam	Clear Lake clay	Mocho silt loam
			Infiltration Rate (mm/hr)		
control (0 ppm)	0.9	6	6.98	1.56	40.20
control (0 ppm)	4.7	6	6.37	1.84	40.44
control (0 ppm)	9	6	6.73	1.53	37.14
Amber 1200D (10 ppm)	0.9	6	4.71	1.32	22.59
Amber 1200D (10 ppm)	4.7	6	1.79	1.33	7.87
Amber 1200D (10 ppm)	9	6	1.57	1.10	4.58
Soilfloc 100D (10 ppm)	0.9	6	3.77	0.64	12.49
Soilfloc 100D (10 ppm)	9	6	1.30	0.58	6.15
$LSD_{0.05}$			0.66	0.33	2.17
p > F[2]			<.0001	<.0001	<.0001
CV (%)[3]			13.3	22.0	8.42

1.water quality: EC = 0.6 dS/m
2. probability of obtaining (by chance alone) an F statistic greater than the computed F value
3. coefficient of variance

Table 3. The effect of polyacrylamide on infiltration rate and concentration of sediment and nutrients in furrow tail water collected from commercial vegetable fields in Monterey County using a recirculating infiltrometer.

Treatment	Total Kjeldahl N	NO_3-N	P (Total)	P (Soluble)	Total Soluble Solids	Total Suspended Solids	Turbidity	Final Infiltration Rate	Total Infiltration
	mg/L						NTU	mm/hr	mm
	Mocho silt loam								
PAM[1]	2.38	1.30	0.85	0.35	478	244	55	7.5	18.4
Untreated Control	6.38	1.95	5.30	0.78	503	2024	1977	3.5	16.9
F-Test	0.079	0.095	0.081	0.046	0.096	NS[2]	0.054	0.028	NS
	Metz complex								
PAM	1.43	23.13	0.35	0.09	1238	156	18	7.9	19.8
Untreated Control	2.25	23.33	1.33	0.16	1220	669	473	7.3	18.9
F-Test	NS	NS	NS	0.088	NS	NS	NS	NS	NS
	Rincon clay loam								
PAM	1.75	22.38	0.68	0.31	840	412	51	2.6	13.7
Untreated Control	3.08	22.58	1.88	0.44	823	1715	1013	4.0	13.9
F-Test	NS	NS	0.078	0.038	NS	NS	NS	0.034	NS
	Salinas clay loam								
PAM	1.38	0.71	0.80	0.36	343	240	59	5.2	18.0
Untreated Control	6.95	1.23	5.40	0.64	213	2759	2437	5.0	26.6
F-Test	0.004	0.018	0.002	0.062	0.009	0.002	0.004	NS	0.009
	Chualar loam								
PAM	2.20	2.03	0.58	0.28	400	306	129	5.8	18.7
Untreated Control	8.45	2.09	3.23	0.46	463	2580	2992	4.2	18.6
F-Test	0.026	NS	0.033	0.085	0.025	0.027	0.024	NS	NS
	Chualar sandy loam								
PAM	0.43	1.52	0.14	0.09	333	36	24	159.0	247.5
Untreated Control	0.73	1.46	0.30	0.12	343	165	183	197.3	349.5
F-test	NS	0.054	0.056	NS	NS	0.034	0.027	0.076	0.051
	Average of All Sites								
PAM	1.57	8.24	0.55	0.24	594	224	54	32.4	57.6
Untreated Control	4.48	8.48	2.80	0.42	583	1592	1459	38.4	76.5
F-test	0.01	0.05	0.01	0.01	NS	0.02	0.01	NS	0.05

1. 10 ppm concentration of Amber 1200D
2. not statistically significant at P < 0.10 level.

Table 4. The effect of polyacrylamide on concentration of sediment and nutrients in sprinkler tail water collected from commercial vegetable fields in Monterey County

Treatment	Total Kjeldahl N	NO_3 -N	P (soluble)	P (total)	Total Disolved Solids	Total Suspended Solids	Turbidity
	---------- mg/L					----------	NTU
	---------- trial 1 ----------						
PAM[1]	2.30	6.2	0.32	0.42	1027	42	40
Untreated	4.78	5.1	0.49	2.37	863	964	2456
F-test	0.003	NS[2]	NS	0.0002	NS	0.004	0.0003
	---------- trial 2 ----------						
PAM	2.54	11.7	1.24	1.26	494	99	89
Untreated	2.96	10.0	0.74	1.34	464	433	785
F-test	NS	NS	NS	NS	NS	0.017	0.007
	---------- trial 3 ----------						
PAM	2.10	18.5	0.94	1.68	491	313	301
Untreated	4.18	21.9	1.08	4.45	510	1959	4645
F-test	0.013	NS	0.01	0.017	NS	0.010	0.007

1. 5 ppm concentration of Amber 1200D
2. not statistically significant at P < 0.10 level.

Potential Causes of Late-Season Foliar Decline In San Joaquin Valley Cotton

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Introduction

Even though California Acala (*Gossypium hirsutum* L.) and Pima *(Gossypium barbadense* L.) yields continue to be among the highest in the U.S., California cotton growers still experience some problems in the late-season period which have so far defied a good description in terms of causes. A recurring problem seen in numerous locations in prior years, and even more widespread in 2004, was a collection of mid- to late-season crop symptoms that have been referred to by a variety of names, including "foliar decline", "foliar or late-season collapse", "bronzing" among others. Symptoms are somewhat varied, and can be as minor as a late season "bronzing" or "reddening" of the upper plant foliage, including reddening of petioles and upper stems of the plant near the newest main-stem meristematic growth. If these effects come about relatively late in the season, after most of the harvestable bolls have been set and lint maturity is quite far along, effects on yield or fiber quality have typically been minor. If the symptoms, and particularly the leaf loss and cessation of terminal meristem growth occur earlier, fiber quality can be impacted in developing bolls, and yields can be reduced due to loss of additional fruiting sites and reduced photosynthetic leaf area to meet boll carbohydrate needs.

According to a large number of growers and PCA's we visited with in recent years at affected fields, two of the biggest problems with this type of "malady" are that it does not always show up in the same field year-after-year (different environmental conditions, changes in crop vigor associated with early-season conditions), and when perceived damage is severe enough, many growers then avoid planting cotton in affected fields the following year, opting instead to rotate to a different crop. This lack of continuity in observance of the problem can make it difficult to determine basic causes or useful responses to this problem. The general symptoms described here have been seen not just in Pima and Uplands in California, but also in Upland cotton fields in Arizona, Texas, parts of Georgia, with some similarity to reported problems in Upland varieties in Brazil. In many cases here and in other states, these symptoms are a good fit for potassium deficiency, matching deficient soil and tissue K levels, but in many in California, symptoms are not associated simply with low soil exchangeable potassium.

Field Observations, Measured Impacts

It is important to state that the broad classification of a "syndrome" or problem described here as a leaf decline is likely to include a collection of plant problems that represent a range of field situations, with one or more primary and secondary causes likely involved. In many fields that could be described as having some variation of foliar decline in recent years, a mix of observations and findings apply, including the following:

- Symptoms vary widely in severity and timing of first occurrence, even in the same field
- In some fields, evidence of Verticillium as foliar injury and vascular staining is very evident and has been confirmed by tissue / pathogen analyses – however, in many fields, there has been no

conclusive evidence of Verticillium.- Verticillium is likely part of what is observed in some, but definitely not all locations investigated for late-season decline symptoms

- Verticillium incidence in these fields has been highly variable with variety, areas of the field and environmental and cultural conditions
- Leaf damage from other pathogens (such as leaf spotting due to *Alternaria*) has often been seen as leaves decline (change color to red or bronze), but UC Pathologists have described these as secondary pathogens causing some damage, but not a primary cause of initiation of the symptoms and decline
- Many of the worst affected areas have been those with a heavy fruit set for the size of the plant and leaf area. This should not be interpreted as indicating this only occurs with large, very high yield plants. Rather, observed problems have been most severe in a wide range of plant sizes with high total boll weight per unit of leaf area remaining on the plant.

Since 1997 in Pima and 2002 in Acala cotton, fields have been evaluated for relative timing, degree of damage in fields where symptoms fit into these broad classifications of "late-season foliar decline". A range of these foliar symptoms have developed and been evaluated in fields in Kern, Kings, Madera and Tulare Counties, and a few fields in Merced and Fresno County with mild but similar symptoms. Depending upon the year and crop conditions, the timing of the damage to foliage and meristems varied from as early as mid-July to as late as mid-September. With a long growing season and a greater number of total bolls needed to achieve high yields in longer maturing Pima and Acala varieties, yields were significantly reduced and components of lint quality affected in many fields where the foliar symptoms occurred starting as early as peak bloom, continuing into fairly severe symptoms and leaf loss greater than 25 percent of total leaf area within the first 2 to 3 weeks after vegetative cutout. In estimates we made in 2002 and 2004, fields with moderate to severe symptoms developing as early as late July to early August had yield losses ranging from about 15 to over 35 percent, with few bolls set after the 16^{th} main stem node in these early-affected plants

Soil and plant tissue nutrient samples were collected for evaluation in over 65 fields showing plant symptoms corresponding with described late-season foliar decline problems since 1997. Potassium deficiency has been implicated in some but not all of these fields. This was not necessarily surprising, since "bronzing" is also a symptom of severe potassium deficiency. Over 90 percent of the fields tested showed low leaf and petiole potassium levels in August and September, but they also showed low N, P and Zn levels. Soil test K and P levels in the 5-15 inch and 15-25 inch zones in affected fields ranged from borderline deficient to sufficient (according to recently developed University of California guidelines). Soil test data does not suggest a clear linkage of the "early decline" symptoms with deficient soil potassium levels, although in some cases low soil K is likely a major contributor to the symptoms seen in plants.

Strip applications of soil applied potassium (200 or 400 pounds K_20 per acre) at seven Kern County Pima and Acala fields have been inconsistent (some positive effects, mostly neutral or slight negative effects) in alleviating "late season decline" symptoms. This includes four sites where soil test exchangeable-K levels were not at borderline levels as defined in UC Potassium Guidelines for cotton. Soil test exchangeable-K levels greater than 140 ppm in the upper 2 feet of soil, combined with low plant tissue K, P, and N values 2 to 4 weeks after peak bloom at these sites suggest that the low tissue K levels and to some degree, even the leaf "reddening" or "bronzing" may not be indicative of limiting soil K, but perhaps may indicate a compromised root system not able to fully access soil K or other nutrients.

In fields where plants were affected relatively early by this foliar decline, plants generally were low vigor, short-stature plants with a definite slowing of growth and damage to meristems and foliage starting as early as the 15th to 18th main stem node (mid- to late-July in fields). The "leaf decline" or "bronzing" symptoms were not restricted, however, to low vigor fields with irregular growth. At least 7 large and relatively uniform Pima fields in Kern County with previously vigorous, 40+ inch tall plants developed very uniform "bronzing" starting in early- to mid-September. In the late-season, plants typically experience a major drop in leaf and stem potassium levels associated with high K requirements for boll development. At this time of the year, it is not unusual to find near-deficient tissue K levels. Particularly in plants with a compromised root system or general low vigor, boll maturation will take place at the expense of new vegetative growth.

Discussion – Findings in Other Areas

In northern California UCCE cotton variety tests with a wide range of genetic material, these "late-season decline" symptoms have similarly been linked more with specific Upland varieties. Very uniform "decline" or "bronzing" occurred as early as mid-July in affected varieties, with moderate yield losses in the most affected varieties. Other varieties in the same fields did not show foliar symptoms. In addition, these fields in northern California were in their first season of cotton production, so there was no long history of buildup of pathogens under cotton production.

In Arizona and Southern California production areas, "bronzing" or "late-season decline" symptoms have also been reported on Upland cotton varieties in recent years, with symptoms most prevalent in fields with the following characteristics: (1) early planted cotton with early leaf or root damage (prior to 6 leaf stage); (2) light-textured soils with generally shallow soil profiles, and (3) soils high in calcium carbonates (*personal communication*, Jeff Silvertooth, Univ. AZ). In some years in Arizona they reported that there was no clear varietal link, since it was observed across many widely-grown varieties. Speculation and field evaluations considered causes ranging from salinity or sodium toxicity, drainage problems, nutrient deficiencies, rapid boll loading, and Verticillium wilt. Some, but not all fields in Arizona with the "bronzing" symptoms tested positive for Verticillium wilt in tissue assays.

Work reported by Richard Percy (USDA-ARS Maricopa, AZ), Hutmacher and Wright (UCCE) looked at Pima varietal differences in early decline symptoms and heritability in a two-field study done in California where the UCCE cotton group selected growers/locations where there was significant field history of early decline late-season symptoms. Trials monitored and rated development of early decline symptoms (bronzing, terminal growth cessation), evaluated leaf and petiole nutrient levels, and evaluated tap root samples in select varieties for damage and extent of rooting. Goals were to establish if any relationships existed between symptom development and in particular tissue K levels. Evaluations of germplasm for relative tolerance to early decline showed low heritability and limited tolerance even with severe symptoms early to mid-bloom. Fruit removal studies were also conducted on a limited number of varieties to identify impacts of fruit load on symptom development. A boll removal evaluation was conducted at two sites where most Pima varieties planted developed at least moderate early decline foliar symptoms within the first 1-3 weeks after peak bloom. When either 1/3 or ½ of total plant boll loads were removed manually during the first four weeks of bloom in these plots, the timing of development of early decline symptoms was delayed by at least 2 weeks and the severity of symptoms was significantly reduced.

Summary and Future Research Needs

There do not appear to be any specific cures to the problems of "late season decline" based on our field evaluations. Data on fruit load / leaf weight or leaf area ratios suggests that where problems have been seen with early leaf loss and leaf "bronzing", growers should monitor plant vigor relative to developing boll load. Based on this discussion, it could be postulated that plants with a relatively heavy boll load and low vigor as indicated by a measure such as height:node ratios may be at greater risk for early leaf decline. Under such conditions, growth regulator applications not called for according to vigor or fruit retention guidelines, or delayed irrigations or other stresses might be expected to amplify the problems. There are numerous observations that some varieties appear to be much less affected than others in terms of time of development and prevalence of “early decline” symptoms. While cooperators in this reported study agree on the existence of varietal differences, some cautions are offered relative to interpretation of the utility of a variety’s ability to remain “green” and avoid “late season decline”. In several variety trials we have observed some varieties which have shown little evidence of “late season foliar decline” also have been relatively low yielding varieties or varieties with a moderate to low boll load per unit leaf area for that site or year. Some caution is warranted against taking the easy way out and just selecting varieties for early decline situations just based on lack of late season decline or leaf symptoms, since low boll loads have consistently been observed to reduce incidence of symptoms.

It might further be hypothesized that field conditions producing root damage or limits to root system development could produce earlier and more severe “leaf decline” symptoms. This hypothesis is based on field observations and tap root measurements made in fields in 1997-1999 in Pima and 2002 and 2004 in Acala. Based on the combination of observations reported here, we suggest that the most likely situation for significant problems with early decline and leaf loss occurs when weak root development (limited lateral root formation, limited rooting depth) is combined with relatively low leaf area and moderate to high fruit loads. However, this is certainly not the only situation where “bronzing” or “reddening” symptoms or early leaf loss has been observed. Some of the overall plant "decline" is likely due in part to nutrient deficiencies (K, P, even N) brought on by a weak root system unable to "explore" soil for adequate nutrients and even water. In many of the tested fields, "deficiency" symptoms in plants under these conditions have not been associated with supposed "deficient" levels of soil K, P or N. Rather, "deficiencies" may largely be a function of inadequate root activity and limited root distribution for adequate uptake of nutrients.

Tissue Testing in Wine Grapes – Leaf or Petiole?

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Introduction

Although petioles have long been accepted as the standard for the preferred plant part for tissue analysis in grapevines, there is growing interest in leaf blade analysis. The reason for this is that some crop consultants believe that because the petiole is a conducting tissue, petiole analysis provides a picture of what is being taken up at the time of sampling, while the leaf may better reflect the nutrients that the plant has accumulated. [This is actually not the case. For example, chloride accumulates in the petiole, even though the symptoms of excess appear in the leaf blades.] Also, the published University of California nutrient guidelines were developed for own rooted Thompson Seedless grapes grown in the San Joaquin Valley. Considering the many different wine grape varieties, grown on various rootstocks in many regions of the state resulting in subtle differences in their nutritional requirements and profound differences in their nutrient uptake, some consultants have developed their own interpretations of optimum nutrient levels for both leaf blades and petioles.

Dellavalle Laboratory has a long history of analyzing plant tissues for grape vines and consultants within the company have extensive experience in interpreting analytical results for both grape petioles and leaves. Both leaf and petiole analysis can be used to successfully evaluate grapevine nutrition. However, this author's personal experience with using both leaf and petiole analysis has resulted in a preference for petiole analysis. There are several reasons for this:

1. Petioles have long been the standard tissue tested for grapes, and all the University of California research and published critical levels are for petioles.
2. When both leaves and petioles of the same vines are analyzed, there are often wider differences between sufficient and deficient levels in the petioles than in the leaves, making it easier to interpret nutrient deficiencies and toxicities in the absence of published critical levels for a given growth stage.

Although petiole analysis remains a reliable standard for evaluating vine nutrient status, some of the critical levels established for own rooted Thompson Seedless grapevines in the San Joaquin Valley are not transferable for other varieties grown on different rootstocks in other regions. This is especially true for nitrogen and potassium.

Nitrogen

The published critical nutrient level for nitrate-nitrogen in Thompson Seedless is sufficient above 500 ppm and deficient below 350 ppm (Christiansen et al., 1978). Many coastal vineyards typically have petiole nitrate levels below 300 ppm (often below 100 ppm), and are doing just fine. With the ever-increasing focus on quality wine grapes, the balance of a vine's vegetative to reproductive growth is key. Excessive vegetative growth can reduce fruit exposure to sunlight, a key to color and flavor development. Inadequate vegetative growth can inhibit the vine's ability to ripen the crop. Ultimately, different wine quality objectives determine the desired level of vigor in a vineyard which has much to do with the vine nitrogen status. High-yielding vineyards are typically of lower vine density planted on fertile soils to favor vigorous vine growth. Many winemakers prefer higher-density lower yielding vineyards for top quality. Clearly there is the need for smaller vines with less vegetative growth when plant densities are above 1000 vines/acre than in an older style low density vineyard with 500 vines/acre. When smaller vines are desired, nitrogen needs are often less and this comes back to the critical level.

Although nitrate-nitrogen levels tend to fluctuate significantly and are not a reliable indicator of nitrogen sufficiency, the parameter is still a useful indicator of nutrient excess. Nitrate-nitrogen levels above 2,000 ppm are associated with excessive growth and berry "shatter." Many vineyards have low nitrate-N levels (below 100 ppm) yet have adequate vegetative growth. Measurement of total nitrogen is commonly performed on leaves for both tree and vine crops. Total-N can also be reliably measured in grape petioles. Petiole total-N levels are much lower than in the leaf typically ranging from 0.7 to 1.4 percent. Although total-N levels cannot be interpreted as "critical levels" as with other elements, they can be correlated to vine vigor to confirm appropriate nitrogen status and relative fertilization requirements.

Table 1 shows some typical bloom time petiole nutrient levels in the Napa Valley. Although nitrate-N levels differ widely for these two samples, total-N levels are similar. Older interpretation guidelines of nitrate-N would have classified sample 1 as excessive and sample 2 as deficient. Because Merlot is more susceptible to berry shatter than other varieties, nitrogen is excessive in this situation. However, vine vigor and the total-N level indicated that nitrogen was adequate for sample 2. This example demonstrates the advantage for evaluation of the nitrogen status using both nitrate-N and total-N on the petiole.

Table 1. Bloom time grape petiole nitrogen levels.

Lab No. 50314		mg/kg	%	%	%
No.	Description	NO3-N	N	P	K
1	Blk 5 Merlot/44-53	**2995**	**1.35**	0.17	3.91
2	Blk 2 Cab Franc/100R	**248**	**1.32**	0.63	3.12

Potassium

Potassium levels much higher than required for Thompson Seedless are needed for wine grapes to adequately ripen. University of California guidelines list the critical petiole potassium value for Thompson Seedless as 1.5 percent at bloom and 0.8 percent at veraison, the onset of ripening, as observed by color change or berry softening (Christiansen, 2000). One of the most severe cases of potassium this author has observed occurred with a petiole potassium level at veraison of 1.0 percent (table 2). The healthy vines in this situation had a petiole potassium level of 1.8 percent. Clearly the critical level in this situation is somewhere between 1.0 and 1.8 percent. In general, 1.5 percent potassium appears to be adequate for wine grape varieties at veraison. Considering this higher level required at ripening, and how potassium levels steadily decline during the season, between 2.5 and 3.5 percent potassium is needed in the petioles at bloom time to maintain a level above 1.5 percent at veraison

Table 2. Veraison grape petiole potassium levels.

Lab No. 79356		%	%	%
No.	Description	N	P	K
1	Zinfandel good	0.63	0.35	**1.77**
2	Zinfandel deficient	0.71	0.49	**1.00**

Other elements

When diagnosing a nutrient imbalance in the field it is often best to separately sample healthy and symptomatic plants. Several years of this author's experience in doing so, analyzing both leaves and petioles of 'good' and 'bad' vines, has shown petiole analysis to be easier to interpret because of the wider difference in nutrient levels. Table 3 shows petiole levels to be a better indicator of manganese toxicity than leaf levels because of the wider spread in the values. (Note: in this case acidic soil conditions result in excess availability of manganese and reduced availability of phosphorus.)

Table 3. Grape petiole and leaf levels.

Description	% N	mg/kg NO3-N	% P	% K	mg/kg Mn
Bad petiole		207	0.06	2.62	**4955**
leaf	1.58		0.08	0.61	415
Good petiole		134	0.09	2.40	**2794**
leaf	1.77		0.11	0.60	303

Conclusion

Although vine nutrition can be monitored using either petiole or leaf analysis, this author's experience has been that petiole analysis can be more clearly interpreted than leaf analysis. The limitations with any tissue analysis are the data gaps in interpretive guidelines. Because of the wider differences in nutrient levels between sufficiency and deficiency with petioles as compared to leaves, petiole analysis remains the preferred method.

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Session V

Irrigation
&
Water Management

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Current Understanding of Regulated Deficit Irrigation in Walnut

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RDI Concept

Regulated deficit irrigation (RDI) is a management strategy that purposely imposes water stress on a crop with the expectation of benefits. A principle underlying RDI is that it imposes water stress by withholding water at a stage of crop growth that responds favorably or at least tolerates stress. A deficit irrigation strategy is not likely to be adopted at the farm level if it results in decreased crop yield or quality to the extent that crop income is consistently reduced.

RDI and Water Use Efficiency

About 30 years ago when some of the earliest research with RDI was initiated in Australia and New Zealand on peaches and pears, the motivation was to develop deficit irrigation strategies that resulted in horticultural benefits such as less pruning, less incidence of disease, and improved fruit quality and value while sustaining or improving yield. This was also the impetus for RDI research that followed in California. At that time, water savings from RDI was considered a secondary benefit primarily for use during periods of drought.

Today, due to competition for California's developed water resources, RDI has been included in a long term, integrated approach to managing California's water resources. Water savings from RDI is the result of using crop stress to reduce crop water consumption (transpiration) and is different from water savings from improved irrigation efficiency at a field, farm, or water district level. Some major components of the integrated approach to managing the state's water resources include conjunctive management of existing surface and groundwater resources, water transfer or marketing programs, and possibly new off-stream surface storage.

RDI has been proposed as having the potential to realize substantial water savings that might be linked to water transfer programs, if implemented in nine permanent crops representing 1.75 million bearing acres in California. Nearly, 200,000 acres of bearing walnuts were identified among this acreage. However, uncertainty about effective strategies for implementing RDI in walnut has been acknowledged.

RDI Strategies in Walnut

Research conducted in the late 1980's at the Kearney Agricultural Center on a hedgerow planting of the variety Chico indicated that bearing walnut orchards are not good candidates for realizing horticultural benefits while saving water by using RDI strategies. After three consecutive years of RDI, at a level of about 13 inches of annual water deficit (33 percent less than historic ETc for walnut), cumulative dry in-shell yield was reduced by 20 percent or 4300 lbs per acre. Walnut quality parameters such as size and off-grade were also negatively affected. Unlike wine grape, pistachio, and other permanent crops, a specific stage of crop growth and development that responded positively or tolerated water stress was not identifiable.

In recent years, the question of whether RDI is applicable to bearing walnut orchards has re-surfaced partly because no information is available on new, predominant commercial varieties such as Chandler walnut. Also, a practical, plant-based irrigation scheduling technique referred to as midday stem water potential (SWP) measured with a pressure chamber was not available for use in the earlier walnut research. Some scientists suggest that RDI in walnut is more feasible since this new technique is available to evaluate real-time orchard water status and to guide deficit irrigation in walnut.

Midday Stem Water Potential (SWP) Measurement in Walnut

Midday Stem Water Potential (SWP) is measured with a pressure chamber during mid afternoon when evaporative demand is high and more stable. In walnut, a terminal leaflet that is still connected to the tree is selected and covered with a water resistant, light reflecting foil bag for a minimum of ten minutes to prevent transpiration through the leaf and to allow the water potential inside the leaflet to equilibrate with the stem and larger canopy. After equilibration, the leaf (still in bag) is excised from the tree and placed inside an air-tight chamber, but a small part of the leaf stem (the petiole) is exposed to the outside of the chamber through a seal. The pressure chamber operator pressurizes the chamber and observes when water just begins to appear at the cut end of the petiole and records the pressure indicated on the gage.

The pressure chamber can be thought of as a device for measuring the suction force as water evaporates from the leaves. Water within the plant mainly moves through very small interconnected cells, collectively called xylem, which are essentially a network of pipes carrying water from the roots to the leaves. The current model of how this works is that the water in the xylem is under tension, and as the soil dries, or for some other reason the roots become unable to keep pace with evaporation from the leaves, then the tension increases. A high value of pressure means high tension and a high degree of water stress. The unit of pressure most commonly used is the Bar (1 Bar = 14.5 pounds per square inch). Because tension is measured, values are reported as negative numbers.

New Investigations with RDI in Walnut

The California Walnut Research and Marketing Board sponsored two experiments focusing on irrigation management in bearing walnuts beginning in the 2002 season and continuing through the 2004 season. One experiment was located in Tehama County and the second experiment was located in San Joaquin County. Similar Randomized Complete Block experimental designs (3 irrigation treatments and 4 replicates) and experimental methods were used at each location. Objectives were to develop management strategies for walnut using a combination of evapotranspiration, soil, and plant-based indicators of water status; and to understand the relationship between SWP and walnut productivity.

The Tehama County orchard was grown on the Maywood sandy loam soil series, consisting of stratified, shallow soils. The orchard was planted in the spring of 1994 using a 30 by 18 foot-spacing (81 trees/ac). Nine acres were involved in the experiment. Two-thirds of the trees were Chandler on paradox rootstock and 1/3 were Chandler on Northern California Black rootstock. Crop growth and development, yield, and walnut quality were measured during the 2002, 2003, and 2004 seasons representing the 9th, 10th, and 11th growing seasons, respectively. Hedgerow pruning occurred during the experiment. The orchard was irrigated using microsprinklers.

The San Joaquin County Orchard was grown on the Cogna loam soil series, a deep well-drained alluvial soil. The orchard is approximately 20 to 25 years old with Chandler on Paradox rootstock and planted in a 32 by 32 foot equilateral triangle arrangement. The orchard has been historically hand pruned at a relatively low frequency and intensity and pruning was minimal during 2002-2004 when the experiment was conducted. The orchard was irrigated using microsprinklers.

This paper primarily presents experimental results from the Tehama County experiment and briefly discusses important contrasts in results between the Tehama and San Joaquin County experiments. More detailed results from both the San Joaquin County and Tehama County experiments will be provided in other venues.

RDI Strategies Evaluated

The cumulative effects of three different irrigation strategies on Chandler walnut were evaluated over three growing seasons. The three strategies were termed low, mild, and moderate stress, respectively. SWP measured one or two times per week was used as the primary tool to differentiate and guide the irrigation strategies. A water balance approach using water meters, soil water content, and soil matric potential monitoring was also used to describe and confirm the application of each strategy. Table 1 summarizes the irrigation strategies for each season at the Tehama County experiment.

Table 1. Summary of monthly average and season average SWP (bars) for the three different irrigation strategies evaluated in Chandler walnut at the Tehama County irrigation experiment, 2002 –2004. Seasonal applied irrigation water (inches/acre) is provided.

Month	2002 Season			2003 Season			2004 Season		
	Low	Mild	Mod	Low	Mild	Mod	Low	Mild	Mod
May	-4.2	-4.5	-5.4	-3.8	-4.2	-4.4	-2.6	-2.7	-2.8
June	-4.0	-4.8	-6.5	-2.5	-4.0	-5.1	-4.8	-5.8	-6.9
July	-3.4	-6.0	-7.8	-2.8	-6.5	-7.5	-5.0	-7.6	-8.9
Aug	-3.3	-6.6	-7.7	-3.2	-7.9	-8.9	-3.2	-6.4	-8.5
Sept	-2.8	-8.9	-9.6	-3.4	-8.5	-10.2	-2.8	-6.0	-8.1
Season Avg	-3.6	-6.2	-7.4	-3.1	-6.2	-7.2	-3.7	-5.7	-7.0
Applied Water (inches)	43.8	31.2	25.8	44.5	26.2	21.7	42.9	26.6	23.3

For Tehama, in the low stress strategy, irrigation water was applied at rates about 10 percent above real-time estimates of crop evapotranspiration (ETc) for walnut. Seasonal SWP averaged between –3.1 and –3.6 bars. Soil-water deficits were commonly between 10 to 30 percent depletion of the available soil water until late in the season at which time they increased to near 50 percent depletion. Gradually increasing water stress was imposed in the mild and moderate stress irrigation strategies. The idea was to impose mild stress in May and June when shoot growth and nut sizing is occurring and then impose more stress by withholding irrigation water from July through September during kernel development. Rates of applied irrigation water ranged from 20 to 40 percent below real-time estimates of ETc for walnut. Soil-water deficits were routinely between 30 and 70 percent depletion of the available soil-water.

Effect of Deficit Irrigation on Walnut Productivity

At the Tehama County experiment, the three-year cumulative dry, in-shell walnut yield for trees irrigated using mild and moderate stress deficit irrigation strategies was reduced by an average of 2,432 and 3,714 lbs/ac, respectively, below the low stress irrigation strategy. Figure 1 illustrates the annual effects of water stress, using SWP as an indicator, on dry in-shell walnut yield. In 2002, a downward trend in yield was apparent. The extent of the reduction was less than 17 percent and in some cases there was no reduction in yield or an increase in yield. Regression statistical analysis suggested that about 36 percent of the yield variability could be associated with crop stress caused by deficit irrigation. Statistical tests for significance indicate this trend in yield reduction may occur at a 95 percent probability level. The downward yield trend continued in 2003, Yield reductions were slightly more pronounced but less than 20 percent. Regression analysis suggested that about 42 percent of the yield variability was attributable to deficit irrigation and the probability of the trend occurring was about 98 percent. In 2004, the downward trend in yield was more pronounced. The slope of the trend line increased from 4.35 and 4.03 in 2002 and 2003, respectively, to 10.2 in 2004. Yield reductions approached 50 percent during the third crop and suggested that the effects of deficit irrigation on walnut yield may accrue over multiple seasons in walnuts orchards similar to the one in Tehama County.

Yield results are not shown for the San Joaquin County experiment. The cumulative yield for the 2002 and 2003 seasons averaged 9 to 11 percent less under the mild and moderate stress deficit irrigation strategies, respectively, in the San Joaquin experiment. The 2004 yield results have not yet been analyzed. Yield reductions associated with deficit irrigation in the San Joaquin County orchard were not nearly as pronounced as in the Tehama County experiment nor were yield reductions statistically different among the irrigation strategies indicating the reductions are not necessarily related to water stress.

Figure 2 illustrates the annual effects of water stress, using SWP as an indicator, on walnut value for the Tehama County experiment. Walnut value is influenced by numerous walnut quality parameters such as nut size, kernel color, and edible yield. In 2002, a slight downward trend was apparent in quality from crop stress imposed by withholding irrigation. The reduction was less than 5 percent and in some cases there was no reduction in crop value. Regression analysis suggested that about 32 percent of the variability in crop value could be associated with crop stress caused by deficit irrigation. Statistical tests for significance indicate this trend in reduced crop value may occur at a 94 percent probability level. The downward trend in walnut value was much more pronounced in 2003. Reductions in 2003 crop value approached 15 percent. Regression analysis suggested a strong correlation between crop value, as influenced by walnut quality, and deficit irrigation. About 84 percent of the variability in crop value was attributable to deficit irrigation and the probability of the trend occurring exceeded 99 percent. Reduction in nut size and darker kernels were important walnut quality parameters affected by deficit irrigation in 2003. Deficit irrigation did not affect walnut quality or crop value at all in 2004. These findings show that undesirable effects of deficit irrigation on walnut quality and crop value can occur and that they can be significant. However, other environmental conditions must coincide with the deficit irrigation for nut quality to be negatively impacted.

Reports for the San Joaquin experiment in 2002 and 2003 indicate that deficit irrigation did not affect walnut quality or related crop value in either year. A report for 2004 is pending.

Gross revenue from walnut production is dependent upon both walnut yield and is based on walnut quality and related crop value. Figure 3 shows the annual effects of water stress, using SWP as an indicator, on crop revenue for the Tehama County orchard. In 2002, a downward trend was apparent. The reduction was less than 20 percent and in some cases there was no reduction in crop revenue. Regression analysis suggested that about 36 percent of the variability in crop revenue could be associated with deficit irrigation. Statistical tests for significance indicate this trend in reduced crop revenue may occur at a 96 percent probability level. The downward trend in crop revenue was slightly more pronounced in 2003. Reductions in 2003 crop revenue approached 30 percent. Regression analysis suggested a correlation between crop revenue and deficit irrigation. About 71 percent of the variability in crop revenue was attributable to deficit irrigation and the probability of the trend occurring exceeded 99 percent. Deficit irrigation continued to reduce crop revenue in 2004. The slope of the trend line increased from 4.98 and 6.49 in 2002 and 2003, respectively, to 10.2 in 2004. Reductions in crop revenue approached 50 percent during the third crop depending upon the extent of crop stress imposed by withholding water and suggest that the effects of deficit irrigation on walnut yield may accrue over multiple seasons in walnut orchards similar to the one in Tehama County.

Effects of deficit irrigation strategies on crop revenue have not been completed at the San Joaquin experiment. Preliminary reports for the 2002 and 2003 seasons suggest the effects of deficit irrigation strategies on walnut yield and quality, thus, crop revenue are not nearly as pronounced as those experienced at the Tehama County experiment.

Summary

These recent experiments in Chandler walnut indicate that one irrigation strategy may not necessarily fit all walnut orchards and growing environments. One of these experiments provides some evidence that RDI strategies can be detrimental to walnut in some production settings. The Tehama experiment agrees with earlier investigations in the 1980's suggesting that walnut may not be an ideal candidate for implementing RDI strategies. A stage of walnut growth or development that benefits from RDI while saving water was not identifiable. In contrast, the preliminary results from the San Joaquin experiment indicates some opportunity may still exist to implement RDI strategies in some walnut orchards and growing environments. Further experimentation is needed to understand the interactions between RDI strategies and orchard design, orchard age, pruning practices, and variable environmental conditions.

These experiences do indicate that use of the pressure chamber and SWP can be a reliable indicator of orchard water status and crop response. SWP can be a valuable irrigation management tool to guide site-specific irrigation management decisions.

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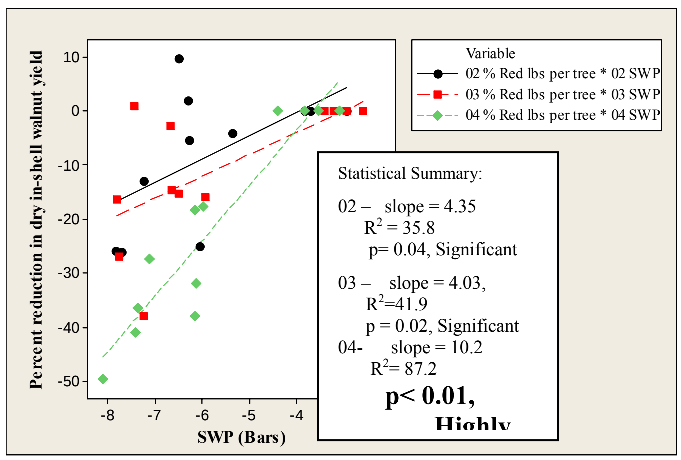


Figure 1. Effect of water stress as indicated by SWP on annual dry in-shell walnut yield of Chandler walnut grown on Paradox rootstock, Tehama County experiment, 2002-2004.

Figure 2. Effect of water stress as indicated by SWP on annual walnut value (based upon walnut quality) of Chandler walnut grown on Paradox rootstock, Tehama County experiment, 2002-2004.

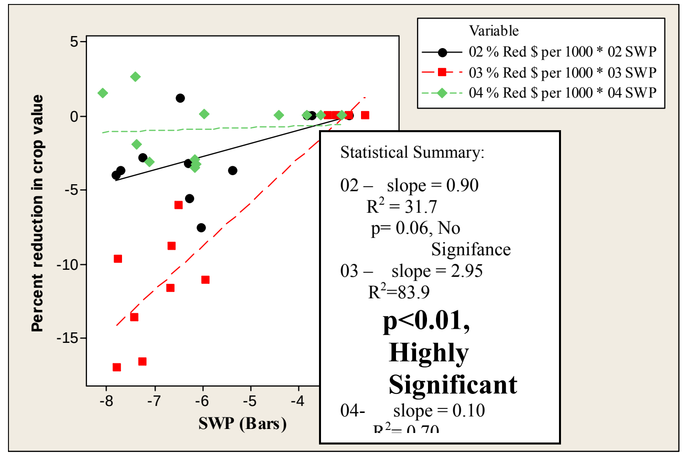
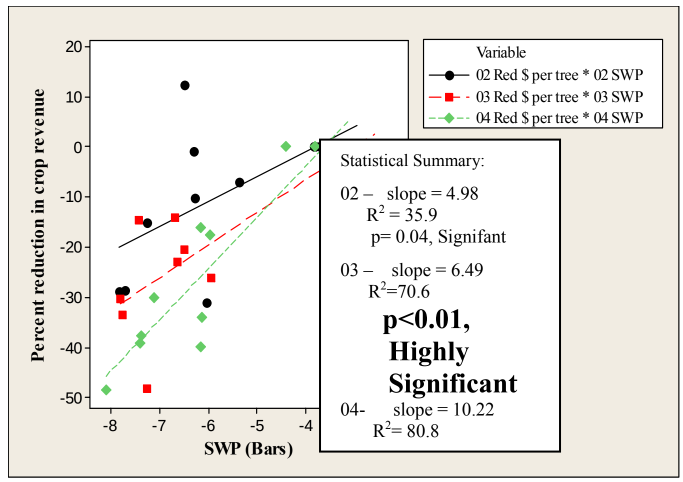


Figure 3. Effect of water stress as indicated by SWP on annual, gross crop revenue (based upon walnut yield and quality) of Chandler walnut grown on Paradox rootstock, Tehama County experiment, 2002-2004.



Improving Nutrient Application Uniformity of Water-Run Fertilizers

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Introduction

Injection of fertilizers, particularly nitrogen, in flood irrigation (furrow and border check) systems is common in California, and it is often the only practical method of fertilizer application during the mid- to late-season. Both commercial fertilizers and dairy manure water are used as water-run fertilizers in the California Central Valley. Applying a pre-determined amount of fertilizer is more easily done with commercial fertilizer since its formulation is known. The nutrient content of dairy manure water is often unknown unless sampling has been on going or a "quick test" analysis is done at the time of irrigation.

The non-uniformity of the irrigation applications is an added complication for using water-run fertilizers in flood irrigation systems. The water intake opportunity times, and therefore the infiltrated water, vary along the field due to the time it takes water to advance down the field. Frequently, and especially in furrow systems, the infiltrated water is greatest at the head of the field and decreases down the field length. Conversely, if a large amount of water is allowed to stand at the end of the field following irrigation, usually the result of allowing the irrigation water to run too long, the tail of the field may receive the greatest infiltrated water. The infiltrated water non-uniformity may lead to nutrient application non-uniformity if the nutrient, e.g. nitrates and ammonium, infiltrates with the irrigation water.

Adjusting the injection rate commonly controls the water-run fertilizer applied during irrigation. This is more easily done using commercial fertilizers as compared to dairy manure water. The method of manure water injection is often a floating pump or a pump on the edge of the dairy lagoon that adds manure water to the low-head flood irrigation system. These pumps are often sized fairly large to provide adequate capacity to lower the lagoon. The injection rate of manure water can be controlled with a valve downstream of the pump. This is often incompatible with the large manure pumps and large pipelines, designed for high flow rates that dairies currently have. Running small flow rates of manure water through large pipelines can result in settling and clogging of the pipeline. In addition, the pumping efficiency of a large pump is decreased when it is forced to operate at a small flow rate. Growers often choose to operate the manure water pump at full capacity during the entire irrigation event, resulting in an over-application of nutrients along with nutrient application non-uniformity. Unfortunately, diary manure water is still often considered a waste to dispose of rather than a useful fertilizer resource.

Improving Nutrient Application Uniformity

Improvement of flood irrigation application uniformity is one approach to improving the uniformity of nutrient applications. Various management techniques, such as furrow torpedoes (Schwankl et al., 1992), surge irrigation (Hanson et al., 1998), and flow rate modification, may result in some improvement in application uniformity. Shortening field lengths, which reduces the difference in intake opportunity times between the top and bottom of the field, is the most effective way of improving irrigation uniformity (Schwankl and Frate, 2004). Shortening field lengths is expensive and inconvenient for growers and is seldom adopted.

Another potential management method of improving nutrient application uniformity is to adjust the timing of nutrient injection during an irrigation event. This strategy of changing the timing of manure water additions hinges on infiltration characteristics varying during irrigation. The infiltration rate is high when water first contacts a dry soil location and then decreases until a final, relatively constant, intake rate is reached. Delaying fertilizer injection until the upper portions of the field have reached the lower, final infiltration rate offsets the effects of the longer water intake opportunity times at the head of the field.

Field Project

Due to the importance of dairy nutrient management, manure water additions to irrigation events were selected as the water-run fertilizer scenario for evaluation. A field project on a Tulare County dairy was conducted during the summers of 2001 and 2002 to evaluate techniques for improving the irrigation and nutrient management of flood irrigation systems applying manure water. Improved irrigation systems should apply water (and water-run nutrients) more evenly on the field and allow the application of the correct amount of water to match crop water demands. Manipulating the timing of manure water additions to the fresh irrigation water was evaluated, along with a number of irrigation water management strategies, to determine if they could improve the nutrient application using a furrow irrigation system.

Multiple irrigation events at the Tulare County commercial dairy were evaluated. For an initial visual evaluation, a tracer (sulfur fertilizer) was added to the irrigation water at various delayed times during the irrigation event. The sulfur fertilizer tracer turned the irrigation water milky in appearance and could be visually tracked as it moved down the furrow. The sulfur fertilizer was not used as a tracer of infiltrated nutrients into the soil profile. From monitoring the tracer, it became evident that nutrient additions to the irrigation water could begin quite late in the irrigation set and still have time to advance to the end of the field before the end of the irrigation set.

From the sulfur fertilizer tracer tests, it was determined that addition of manure would start when clean irrigation water had advanced approximately 900 feet along the 1200-foot long field. This resulted in the advancing front of the manure water / freshwater mix catching the advancing front of the freshwater at the 1050 foot furrow distance. It took the clean irrigation water 4 to 5 hours to advance to 1050', but it took the delayed manure water-advancing front less than an hour to reach the 1050' mark.

Water samples were collected at frequent time intervals (e.g. 15 minutes but sometimes modified to more accurately measure any water quality changes) and at multiple locations along the furrow. These water samples traced the movement of the manure water along the furrow and provided the spatial and temporal distribution of water quality during the irrigation event.

RBC flumes were placed in furrows to monitor furrow flow rate. The field was surveyed and its slope was determined. Advance / recession measurements were also gathered. The results from the irrigation evaluation were used to provide inputs to a two-point Volume Balance furrow irrigation model (Walker and Skogerboe, 1987) used to determine infiltrated water amounts along the furrow and to determine the irrigation uniformity.

As described below, the results of delaying additions of manure water to the irrigation water during an irrigation event were very promising. By delaying addition of manure water to irrigation water, not only could a lesser amount of nutrient be applied using the existing manure water application equipment, but also the nutrients could be applied more uniformly.

Water quality

The fresh irrigation water / manure water mix used for irrigation had approximately 100 mg/l ammonium and 150 mg/l total nitrogen. For example, nitrogen samples taken 30 minutes after manure water traveled 900 ft. along the field recorded the following NH_4-N (mg/l) / Total Nitrogen (mg/l) levels: Head of field – 101/ 155, 300' along field – 106 / 155, 600' along field – 107 / 131, and at 900' along field – 101 / 139. There was little change in ammonium content and a slight change in total nitrogen of the water along the furrow. As is common with dairy manure waters, there was no nitrate in the manure water because dairy manure ponds are most often anaerobic. The manure water used for irrigation was relatively low in solids since the dairy had a solids separator and a multi-pond manure handling system.

For this manure water, the majority of the nitrogen nutrients were tied up in the ammonium form and in the organic form as small particles in suspension. The constant nitrogen content of the irrigation water along the furrow may not hold for manure water high in large particles that settle out at the head of the field. In such a case, it is possible that the organic nitrogen content of the water would decrease more significantly as it moves down the furrow.

Infiltration and Irrigation Uniformity

An early-season irrigation event following cultivation was monitored. Water advanced across the field in approximately 5.5 hours. The average irrigation depth applied was 7.1 inches with irrigation distribution uniformity of 64% (Table 1). As with many dairies in Tulare County, the irrigation system was operated to minimize tailwater runoff. Therefore, once water advanced to the end of the field, it was allowed to run only a short period of time before the irrigation set was switched. This resulted in the top end of the field receiving substantially more infiltrated water than the tail end of the field. For the monitored irrigation event, the head of the field received approximately 9.4 inches of infiltrated water while the tail of the field received approximately 3.1 inches.

If manure water had been added to the irrigation flows during the entire irrigation event, the uniformity of nitrogen application would have been the same as the water application uniformity – 64%. The top end of the field would have received significantly more nitrogen than the tail of the field. Adding manure water during the entire irrigation event would have resulted in the field receiving an average of 242 lbs. of nitrogen per acre (Table 1).

When manure water was added to the irrigation water after freshwater had advanced 900' along the furrow, the manure water application uniformity was increased from 64% to 69%. At least as importantly though, the average nitrogen application to the field was reduced from 242 lbs/acre to 86 lbs/acre (Table 1). A major challenge for dairies injecting manure water is applying too many nutrients during an irrigation event. When injecting during the entire irrigation event, the manure water injections could be "valved back" to reduce the injection rate. Injecting during only the latter stages of the irrigation event would achieve the same lowered nutrient application while improving the nutrient application uniformity.

Table 1. Irrigation evaluation results of various manure water irrigation strategies. Field is furrow irrigated and 1200 ft. long.

Nutrient Application Strategy	Avg. Irrigation Amount (in.)	Irrigation Uniformity (DU - %)	Avg. Manure Water Infiltrated (in)	Manure Water Uniformity (DU - %)	Nitrogen Applied (lbs/ac)
Manure water added during entire irrigation	7.1	64	7.1	64	242
Manure water started when freshwater advance = 900'. Shut-off when advanced to end of field.	7.1	64	2.5	69	86
Simulation 1: Manure water started when freshwater advance = 900'. Shut-off = end of field advance + 1 hr.	7.6	70	3.0	69	102
Simulation 2: Manure water started when freshwater advance = 1000'. Shut-off when advanced to end of field.	7.1	64	0.9	91	31
Simulation 3: Manure water started when freshwater advance = 1000'. Shut-off = end of field advance + 1 hr.	7.6	70	1.4	88	49

With the field data available for model verification, simulations of other irrigation and manure timing strategies were investigated using a two-point Volume Balance Model. They included:

Simulation 1:
Manure water additions began when freshwater reached 900 ft. along the furrow. Irrigation water was shut off one hour after it reached the end of the field. This strategy would result in nutrient application uniformity nearly the same as the irrigation uniformity (69% vs. 70% - Table 1), but the average nitrogen application amount is reduced from 242 lbs/acre for the continuous manure water addition strategy to 102 lbs/acre for this delayed manure water addition practice.

Simulation 2:
Freshwater was allowed to advance 1000 ft. along the furrow before manure water was added to the irrigation water. The irrigation supply was shut off shortly after water reaches the end of the field. The result of this practice would be a small amount of nitrogen (31 lbs/acre) applied to the field and it is applied very uniformly (DU = 91%). This would be a good strategy if frequent, small applications of nitrogen were desired.

Simulation 3:
In this delayed manure water addition strategy, manure water was added to the irrigation water after freshwater has advanced to 1000 ft. Irrigation is allowed to continue for 1 hour after water advances to

the end of the field. This strategy would allow the application of a limited amount of nitrogen to the field (49 lbs/acre) while applying it with a high uniformity (88%). Of all the strategies evaluated, this would be preferable since it increases both the irrigation and nutrient application uniformities (see Table 1) compared to adding manure water during the entire irrigation event stopped when water reaches the end of the field.

Summary

Delayed addition of manure water holds promise as a means of improving nutrient application uniformity and of applying less nitrogen during an irrigation while still using existing high flow rate manure water pumps and pipelines. Two disadvantages of delaying manure water applications are that there is a delay once manure water pumps are turned on until manure water reaches the irrigated field. For the field evaluated in this study, that delay was approximately 20 minutes. Secondly, it is quite common for dairies to be irrigating multiple fields at the same time, often at different locations on the dairy and utilizing complex piping systems, to deliver the water. This makes delayed manure water additions, as well as any form of manure water nutrient management, a complex and sophisticated task.

Acknowledgement

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Effect of Fertigation Strategy on Nitrate Availability and Nitrate Leaching under Micro-Irrigation

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Introduction

Micro-irrigation has the potential of precisely applying water and fertilizer both in location and in quantity. Fertigation is the process of applying fertilizers through the irrigation water. However, under micro-irrigation, soil water content, root distribution, and solute concentration vary spatially around the drip line. This variability could result in fertilizer applied through the irrigation system being leached beyond the area of the highest root density unless careful management of both water and fertilizer is practiced.

A recommendation frequently used for fertigation with micro-irrigation is to inject during the middle one-third or the middle one-half of the irrigation set time to insure a field-wide uniformity of applied fertilizer equal to that of the irrigation water and a relatively uniform chemical distribution in the root zone. However, a common practice is to fertigate for a short period of time, i.e. one or two hours, mainly because of convenience. Short fertigation events could result in relatively nonuniform distributions of fertilizer in the soil profile that could affect the availability and leaching of a fertilizer that moves readily with water flowing though the soil. This project investigated the distribution of nitrate in the root zone for various soil types, micro-irrigation systems, and fertigation strategies. A manual on fertigation with micro-irrigation is being developed.

Methods and Materials

The computer simulation model HYDRUS-2D was used to assess the effect of various fertigation strategies on water and nitrate distribution in the soil profile and on nitrate leaching. Outputs of the model include distributions of nitrate and soil water content in the soil profile and a mass balance of nitrate.

Fertigation scenarios evaluated by the model are:

- micro-irrigation systems were 1) SPR - microsprinkler (citrus) using a sprinkler discharge rate of 5 gph; 2) DRIP - surface drip irrigation (grapes) using 1 gph emitters; 3) SURTAPE - surface drip irrigation (strawberries) using drip tape with a tape discharge rate of 0.45 gpm/100ft; and 4) SUBTAPE - subsurface drip irrigation (tomatoes) using drip tape buried at 8 inches deep with a tape discharge rate of 0.22 gpm/100 ft.

- soil types - sandy loam (SL), loam (L), silt clay (SC), anisotropic silt clay (AC) with a ratio of horizontal hydraulic conductivity to vertical conductivity equal to 5.

- fertigation strategies include 1) B – inject for 2 hours starting one hour after start of irrigation, 2) M - inject for 2 hours in the middle of the irrigation set, 3) E - inject for 2 hours starting 3 hours before cutoff of irrigation water, 4) M50 – inject during the middle 50% of the irrigation set time, and 5) C - inject continuously during the irrigation set starting 1 hour after start of irrigation and ending 1 hour before irrigation cutoff. For SURTAPE, injection time for B, M, and E was 0.5 hours.

Assumptions used for the modeling include 1) maximum evapotranspiration conditions and an irrigation efficiency of 85%, 2) an irrigation set time sufficiently long to apply the desired amount of water, 3) no nitrate in the soil profile at the start of simulation, 4) quasi-equilibrium soil moisture content patterns at the start of the fertigation scenarios, and 5) the same amount of nitrogen injected for each scenario.

Results and Conclusions

Nitrate concentrations shown in the Fig. 1 to 4 are relative concentrations, defined as the ratio of the actual concentration in the soil to the concentration in the irrigation water of the 2-hr injection time. The irrigation water concentrations of the M50 and C strategies were adjusted to reflect the longer injection times compared to the 2-hr injection. Nitrate distribution for DRIP (loam) showed a leached zone in the immediate vicinity of the drip line for the B strategy (Fig. 1). Nitrate accumulated near the boundary of the wetted pattern. Nitrate was distributed in the vicinity of the drip line for the E strategy with concentrations much higher compared to the B strategy. The M50 and C strategies resulted in a more uniform nitrate distribution compared to the other strategies. Similar patterns were found for the sandy loam (data not shown).

Nitrate distributions for DRIP (silt clay) differed from those of the loam and sandy loam. Water ponded on the soil surface caused downward water flow instead of radial flow found in sandy loam and loam soil. The downward flowing water resulted in a horizontal band of nitrate for the B strategy (Fig. 2). The E strategy resulted in a narrow zone of nitrate near the surface. Nitrate was dispersed more uniformly in the upper part of the soil profile for strategies M50 and C.

Nitrate distributions for SUBTAPE (sandy loam) showed a zone of leached soil in the immediate vicinity of the drip line for the B strategy with a zone of nitrate beyond the leached soil due to the relatively long irrigation time after fertigation (Fig. 3). For the E strategy, however, relatively high nitrate concentrations occurred in the immediate vicinity of the drip line. Upward movement of nitrate was much higher for the B strategy due to the relatively dry soil above the drip line at the beginning of fertigation compare to the E strategy. Nitrate distributions of the M50 and C strategies showed a more uniform distribution over the soil profile compared to the 2-h fertigation strategies.

Nitrate distributions of SPR reflected the water application pattern of the microsprinkler. Most of the water applied by this sprinkler occurred within about 4 ft from the sprinkler (data not shown). Injecting near the beginning of the irrigation for a short time period leached most of the nitrate down in the soil profile, whereas injecting near the end of the irrigation left most of the nitrate near the soil surface (Fig. 4).

Similar nitrate distributions occurred for SURTAPE for all fertigation strategies except for the E strategy (data not shown). The reason for this behavior was the relatively small irrigation times (3.2 hours) of this scenario. Thus, for the short fertigation events, which were 0.5 h, irrigation times following fertigation were relatively small.

Nitrate moved more in the horizontal direction than in the vertical for the anisotropic silt clay scenarios (data not shown).

Conclusions

In general, less nitrate was leached from the root zone for the E strategy compared to the other strategies for DRIP and SPR. Also, a more continuous fertigation resulted in a more uniform distribution of nitrate in the soil. The results were less conclusive for SUBTAPE. Upward movement of nitrate above the drip line appears to have resulted in little differences in nitrate leaching among the different strategies. Little difference in nitrate leaching also occurred for SURTAPE, mainly because of the short irrigation set time. Nitrate distributions around the drip line were relatively similar for all strategies compared to the other micro-irrigation systems. However, more nitrate leaching occurred for SURTAPE compared to the other micro-irrigation methods, reflecting the shallow root depth, about 12 inches, of the crop (strawberries) used for this scenario. Leaching was the highest for sandy loam compared to the other soil types.

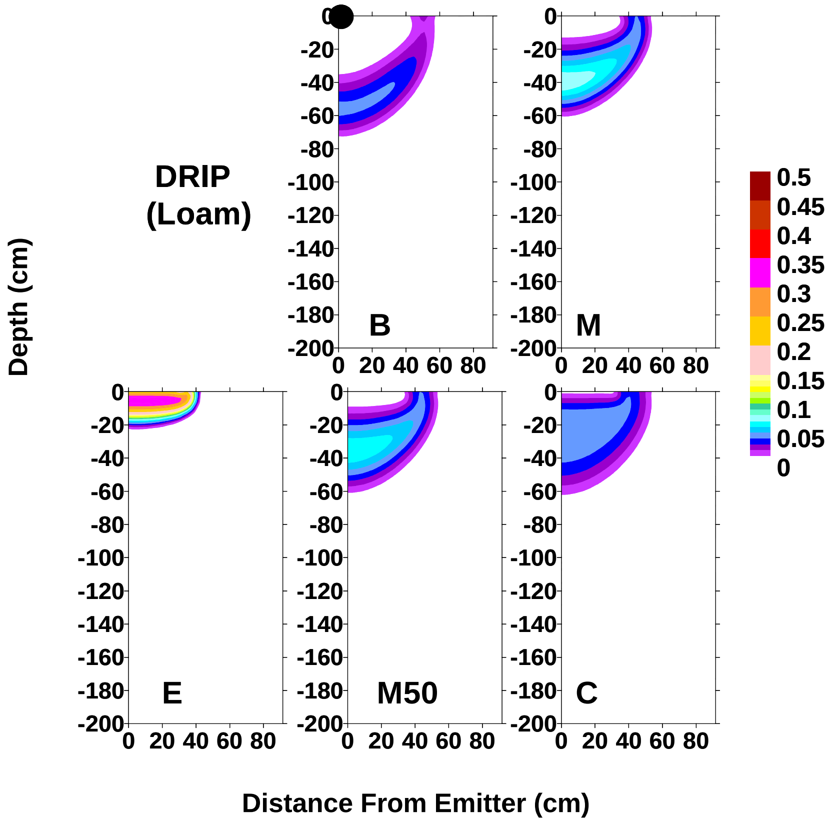

Figure 1. Nitrate distributions around the drip line for DRIP (Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

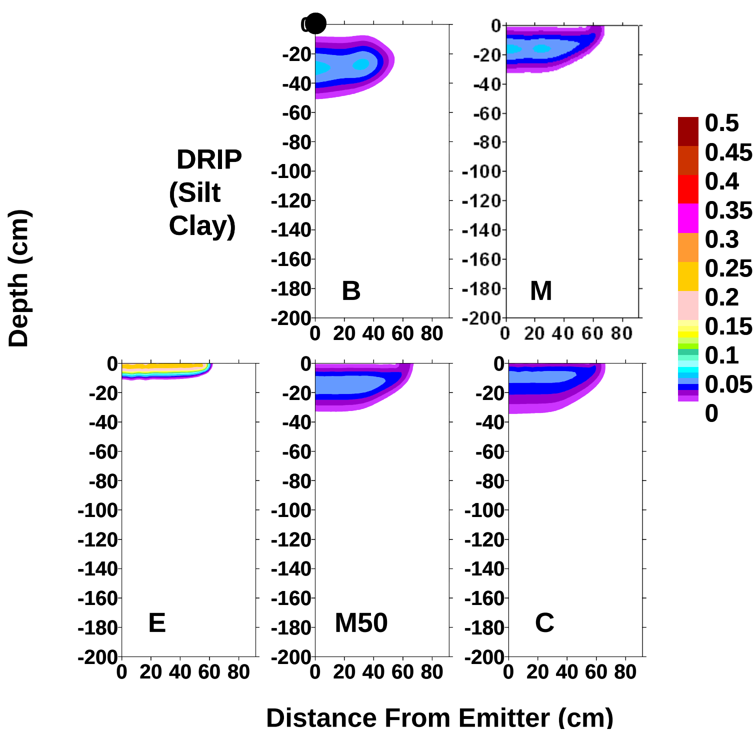

Figure 2. Nitrate distributions around the drip line for DRIP (Silt Clay) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

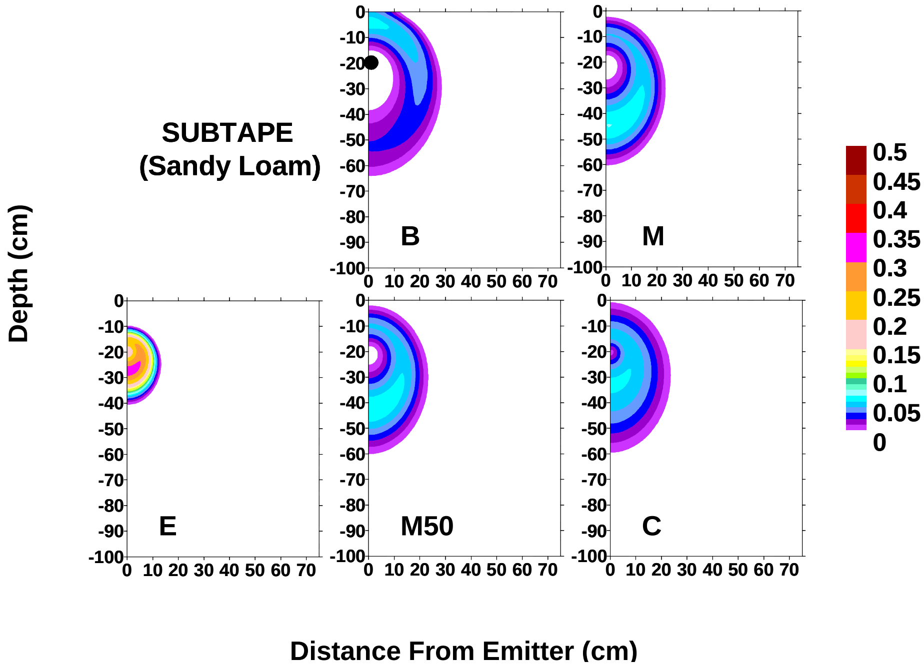

Figure 3. Nitrate distributions around the drip line for SUBTAPE (Sandy Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

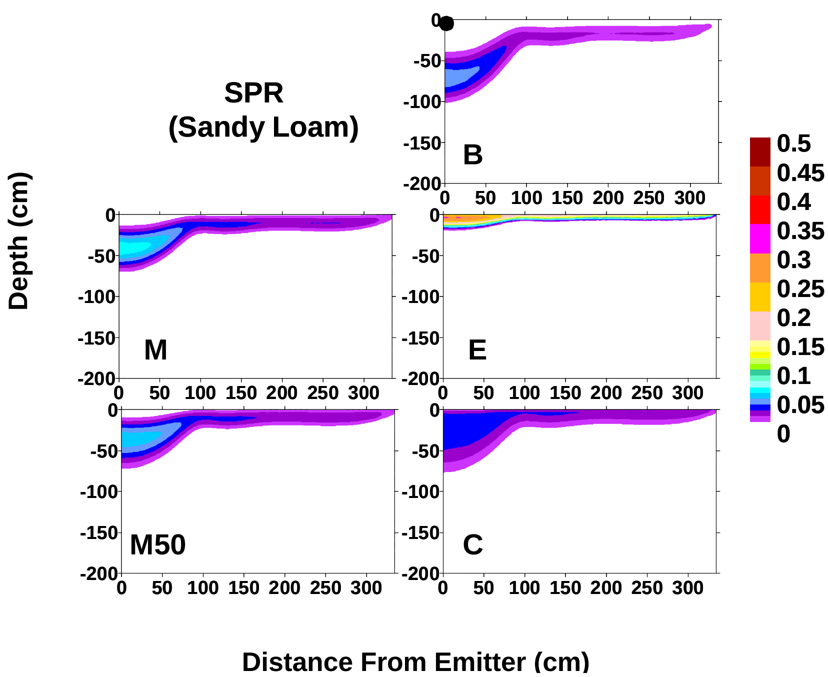

Figure 4. Nitrate distributions around the drip line for SPR (Sandy Loam) for the different fertigation strategies. The black dot is the emitter. 1 ft = 30.5 cm.

Drip Irrigation Improves Potential Profits for Growing Peach

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Introduction

Many older peach and nectarine orchards in California are irrigated by flood systems such as basins, borders, and furrows. These types of systems are relatively simple and inexpensive to install, but typically require high labor input during irrigation and often tend to result in low irrigation uniformity and efficiency because of poor water distribution within the field (Kruse et al., 1990). Consequently, many newer orchards are being equipped with pressurized irrigation systems such as sprinklers, microsprays, surface drip, and subsurface drip. Potential advantages of pressurized systems include improved water control and distribution uniformity, enhanced plant growth and yield, better application of fertilizer and other agrichemicals, reduced weed control costs, and improved cultural practices (Kruse et al., 1990). Disadvantages may include higher capital and energy costs, and increased maintenance requirements. Currently, in California, there are approximately 50,000 acres of peach, nectarine, and apricots irrigated by flood systems and over 77,000 acres irrigated by pressurized systems, most of which is sprinklers and microsprays (Burt et al., 2002).

In 1999, we planted a large study to evaluate the potential of various irrigation systems and scheduling strategies to improve growth and early production of young peach trees. We hypothesized that trees irrigated with pressurized systems would develop faster and produce significantly more fruit early on than those irrigated with surface systems, due to more precise water application. We also hypothesized that frequent irrigations (e.g., daily irrigations) would be more beneficial to tree performance than less frequent irrigations (e.g., weekly irrigations or greater) because the later would expose trees to short-term periods of water stress during each irrigation cycle (Fereres and Goldhamer, 1990). Most growers using furrow apply irrigations 1-2 times per month, while those using microsprays typically irrigate weekly. Drip irrigation is often applied daily during late spring and summer months. Our results indicated that, at the end of three growing seasons, surface and subsurface drip irrigation reduced soil evaporation and significantly improved growth (as indicated by trunk size and pruning weights) and early production (as indicated by marketable yield) of young peach trees over other irrigation methods commonly used in central California (Bryla et al., 2003). The objectives of the current study presented here was to compare the costs and benefits of various irrigation systems in mature, full-bearing peach trees.

Methods

The research was conducted on a 4-acre field of early-ripening 'Crimson Lady' peach trees on 'Nemaguard' rootstock planted in April 1999 at the USDA ARS San Joaquin Valley Agricultural Sciences Center in Parlier, Calif. Trees were spaced 6 x 16 ft. apart and pruned to a perpendicular-V training system (DeJong et al., 1994).

Seven irrigation treatments were evaluated at the site including two furrow, one microspray, one surface drip, and three subsurface drip systems. Furrow treatments were flood irrigated either weekly or biweekly in 3-ft.-wide furrows located on each side of the tree row. Microspray treatments were irrigated weekly with one 5 gph fan jet emitter (≈10-ft. diameter, 230^{o} spray pattern) located near the base of each tree. Surface and subsurface drip treatments were irrigated daily by drip tubing with 0.5 gph turbulent flow emitters spaced every 18 inches. Surface drip tubing (one lateral per row) was placed near the tree trunks along the row. Subsurface drip tubing was buried 15-18 in. deep with laterals placed between rows (one lateral per row, 8 ft. from the row), on each side of the row (two laterals per row, 4 ft. from the row), or both between and on each side of the row (three laterals per row). Treatments were arranged in a randomized complete block design and replicated six times. Each treatment block consisted of three rows of eight trees; measurements were made on the middle six trees.

Irrigations were scheduled in each treatment to replace 100% of the estimated crop evapotranspiration (ET) requirements; crop ET estimates were obtained from representative trees growing in a weighing lysimeter (see Johnson et al., 2002 for details). Fertilizer (UN32) was added a rate of 80 lb N per acre per year. Trees were summer pruned in July and dormant pruned in January each year. Fruit were commercially thinned and harvested beginning the third year (2001) after planting. Fruit were picked 2-3 times per year in late May. Weeds, insects and diseases were controlled with herbicides and pesticides as needed.

All measurements reported in the present study were made during the 2002-2004 growing seasons. Weather data was obtained from a nearby weather station (California Irrigation Management Information System, CIMIS, Station No. 39, Parlier, Calif.). Irrigation was monitored at least weekly with turbine water meters installed at the inflow to each treatment system. Summer and dormant pruning weights were measured following each commercial hand pruning. Fruit were weighed at harvest and measured for size using an automatic fruit sorter.

Results and Discussion

Weather conditions

Precipitation was higher than normal in spring 2003, especially in April and early May when fruit were sizing, and lower than normal in 2002 and 2004 (Table 1). Evaporative demand on the crop, as indicated by reference ET, was also lower in 2003 (Table 1), reducing the overall irrigation required by the trees during that season. Approximately 3.4 acre-ft. of water was applied to each irrigation treatment in 2002 and 2004, but only 2.9 acre-ft was applied in 2003.

Vegetative growth

Pruning costs were highest each year when trees were irrigated daily by surface drip and subsurface drip with two or three laterals, and lowest when trees were irrigated weekly by microsprays (Table 2). Microsprays probably produced less vegetative growth because soil evaporation rates are often quite high following this type of irrigation, which thus reduces the amount of water available to the trees and results in tree water stress (Bryla et al., 2005). When trees were irrigated by microsprays at 150% crop ET (to adjust for soil evaporation), pruning weights increased by nearly 6 tons/acre over the 3 years of the study (data not shown) and were more similar to those measured on drip-irrigated trees. Pruning costs were also low when trees were irrigated with one lateral of subsurface drip or biweekly by furrow (Table 2).

Fruit production and profits

Marketable yields and gross returns were similar among irrigation methods in 2003 when spring weather conditions were wetter than usual. However, in drier years, yields were significantly higher when trees were irrigated daily by surface drip or by subsurface drip with two or three laterals than when trees were irrigated by other methods (Table 3). Trees irrigated biweekly by furrow or weekly by microsprays, on the other hand, produced the lowest yields. These treatments also produced more non-marketable fruit on average and fewer large-sized fruit (40s and 50s) (Table 4). Microspray irrigation at 150% crop ET increased marketable yields to 29.3 tons/acre over 3 years, which was still $2000-3000 less per acre than either surface drip or subsurface drip with two or three laterals (Table 3). Even when additional water is added by microsprays or furrow, these methods tend to produce lower yields than frequent drip irrigations because short episodes of water stress develop between irrigations and reduce fruit growth (Bryla et al., 2004). Daily drip irrigation eliminates these cycles of water stress and thereby optimizes fruit growth.

More than one lateral of subsurface drip was needed in our study for optimal fruit production (Table 3). It may also be prudent to use more than one lateral for surface drip in order to reduce the risk of reduced yields during irrigation system failures. Two lines of surface drip (spaced sufficiently far enough apart) would double the amount of water stored in the soil profile, allowing the trees to maintain water uptake until the failed system is repaired.

Irrigation system costs

Installation costs per acre are comparable between microspray and two-line drip systems, though drip system costs vary considerably depending on the type of drip tubing used (Table 5). Pumping, filtration, and fertigation are similar among microspray, surface drip, and subsurface drip systems, and were therefore not considered in our cost analysis. Furrow system costs were also not included because very few of these systems are being installed in peach orchards anymore.

When considering the cost of each system, maintenance costs also should be considered as part of the long-term budget. Microspray systems are easily checked for plugging and damage, but because the tubing and jet emitters are exposed, these systems are subject to damage from cultural practices, animals, and insects. Some growers reportedly will not begin microspray irrigations without first checking the orchard for leaks and plugs. In high-density plantings, close tree spacing may result in a need to use jets with smaller orifices, which increase filtration and maintenance requirements. Closer spacing will also results in leaf and trunk wetting and may increase tree susceptibility to disease.

Surface drip systems are also easy to check for leaks and plugs, but are much less susceptible to damage and eliminate trunk wetting. Subsurface drip systems, in contrast, are difficult to check for leaks and plugs, and to make repairs, but tend not to interfere with cultural practices. Subsurface drip systems can be turned on at anytime, even during harvest. Orchard topography can significantly affect the longevity of subsurface drip systems. One dealer consulted indicated that a number of growers who had installed subsurface drip (buried to 6 inches) had to replace their tubing after only 6 years because the emitters had become plugged with soil. Plugging sometimes happens in orchards with steep slopes or undulating soil. In these cases, as lower parts of the system drain, upper parts create a vacuum inside the tubing and pull wet soil into the emitters. Proper system design (e.g., air vents, no-drain pressure compensating tubing) and maintenance will help limit this problem. Root intrusion may also plug emitters, but can be minimized with use of Treflan-impregnated emitters. Treflan emitters were used in our study. We found no evidence of root intrusion thus far. Drip tubing with Treflan-impregnated emitters is relatively expensive (Table 5) and research is needed to determine if the extra cost is warranted for peach.

Water savings

Surface drip and subsurface drip with two or three laterals significantly increased average irrigation water use efficiency, defined as tons of fruit produced per acre-ft. of irrigation water applied (Bos, 1985), compared to other irrigation methods (Table 6). Differences among treatments were most apparent in drier years.

Irrigation water use efficiency was highest in 2003 for all treatments because yields were high (Table 3) and irrigation requirements were low (Table 1) that year.

Summary

Both surface and subsurface drip increased growth and production and improved water use efficiency in peach compared to trees irrigated by more traditional furrow or microjet irrigation systems. In terms of profitability, however, surface drip was clearly the best system for irrigating the trees because it consistently produced high marketable yields and had the lowest installation and maintenance costs. Though only one line of surface drip tubing was used per row in our study, it may be prudent to use two laterals per row for commercial production to reduce risks of excessive water stress during irrigation system failures.

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Table 1. Monthly and long-term average precipitation and reference evapotranspiration (ET) measured over the growing season in Parlier, Calif.[1]

Month	Precipitation (in)				Reference ET (in)			
	2002	2003	2004	Long-term average	2002	2003	2004	Long-term average
March	1.22	0.80	0.87	2.24	3.76	4.10	4.19	3.69
April	0.27	2.12	0.02	0.78	5.06	4.38	5.78	5.25
May	0.06	0.68	0.04	0.42	7.39	6.57	7.49	6.84
June	0.00	0.00	0.01	0.34	8.17	7.99	7.84	7.82
July	0.00	0.00	0.01	0.16	8.31	7.84	8.07	8.12
August	0.00	0.02	0.01	0.17	6.82	7.15	7.09	7.10
September	0.00	0.01	0.01	0.24	5.23	5.56	5.46	5.23
Season total	1.55	3.63	0.97	4.35	44.74	43.59	45.91	44.04

[1]Weather data was obtained from a CIMIS weather station.

Table 2. Summer and winter pruning weights of 'Crimson Lady' peach trees irrigated by furrow, microjet, surface drip, or subsurface drip (SDI) systems.

Irrigation system	Pruning weights (tons/acre)						
	2002		2003		2004		Three-year total
	Winter	Summer	Winter	Summer	Winter	Summer	
Furrow (7 d)	2.1	6.8	2.3	6.5	1.5	5.2	24.4
Furrow (14 d)	1.9	6.2	2.0	5.7	1.6	5.3	22.6
Microspray	0.9	5.0	1.8	5.6	1.5	4.4	19.2
Surface drip	2.1	7.6	2.3	6.8	1.9	5.6	26.3
SDI (one lateral)	1.4	6.2	1.7	5.7	1.5	4.4	21.0
SDI (two laterals)	2.0	7.9	2.4	7.6	1.9	6.3	28.1
SDI (three laterals)	1.9	7.4	2.2	6.5	1.7	5.3	25.0

Table 3. Marketable yield and gross returns from 'Crimson Lady' peach trees irrigated by furrow, microjet, surface drip, or subsurface drip (SDI) systems.

Irrigation system	Marketable yield (tons/acre)[1]				Gross returns ($/acre)[2]			
	2002	2003	2004	Total	2002	2003	2004	Total
Furrow (7 d)	7.7	11.0	9.9	28.7	7,360	10,480	9,430	27,270
Furrow (14 d)	6.9	11.0	8.0	25.9	6,560	10,480	7,560	24,600
Microspray	6.0	11.8	9.4	26.9	5,730	11,180	8,880	25,570
Surface drip	8.7	11.7	11.0	31.9	8,310	11,150	10,480	30,270
SDI (one lateral)	6.8	12.0	9.5	28.3	6,500	11,390	8,980	26,870
SDI (two laterals)	9.1	11.8	10.6	31.3	8,670	11,210	10,070	29,760
SDI (three laterals)	8.9	12.2	11.3	32.5	8,480	11,640	10,740	30,860

[1]Marketabe fruit were ≥2¼ inches in diameter.
[2]Values were calculated from May peach prices received by growers as reported by the USDA National Agricultural Statistics Service.

Table 4. Size distribution of fruit harvested from 'Crimson Lady' peach trees irrigated by furrow, microjet, surface drip, or subsurface drip (SDI) systems.

Irrigation system	Fruit size distribution (%)[1]				
	Non-mark.[2]	Small	Medium	Large	Very large
Furrow (7 d)	14.5	22.2	44.6	18.5	0.2
Furrow (14 d)	19.3	20.7	42.3	17.5	0.2
Microspray	17.9	27.6	40.8	13.5	0.1
Surface drip	9.4	18.2	44.7	27.0	0.7
SDI (one lateral)	12.5	20.3	43.4	23.3	0.5
SDI (two laterals)	9.1	16.6	42.6	30.4	1.4
SDI (three laterals)	9.8	17.4	44.7	27.3	0.8

[1]Values were averaged over the 2002-2004 growing seasons.
[2]Non-marketabe fruit.

Table 5. Materials[1] and labor costs per acre for installing microjet and drip irrigation systems. All costs were priced in December 2004 for 40 acres of tree spaced 6 x 16 ft apart.

Irrigation system	Laterals per row		
	One	Two	Three
Microsprays[2] (.620/.720 tubing, stakes & leader tubing, and fan jet emitter)	$412	n/a	n/a
Drip[3] (non-pressure compensating tubing)	$195	$389	$583
Drip[3] (pressure compensating tubing)	$216	$433	$649
Drip[3] (no-drain pressure compensating tubing)	$235	$471	$706
Drip[3] (non-pressure compensating tubing with Treflan impregnated emitters)	$362	$721	$1,082

[1]Materials costs are for tubing and emitters only; other costs such as, pumps, filter stations, fertilizer injectors, and irrigation manifolds are assumed to be equal among the irrigation systems.
[2]One fanjet emitter per tree with a 230^{o} wetting pattern.
[3]20 mm tubing with 0.4 gph emitters spaced every 40 in.

Table 6. Irrigation water use efficiency (IWUE) of 'Crimson Lady' peach trees irrigated by furrow, microjet, surface drip, or subsurface drip (SDI) systems.

Irrigation system	IWUE (tons fruit/acre-ft water)			
	2002	2003	2004	Average
Furrow (7 d)	2.30	3.85	2.94	3.03
Furrow (14 d)	2.05	3.87	2.36	2.76
Microspray	1.79	4.10	2.77	2.86
Surface drip	2.58	4.05	3.26	3.33
SDI (one lateral)	2.02	4.14	2.79	2.99
SDI (two laterals)	2.76	4.09	3.20	3.33
SDI (three laterals)	2.68	4.27	3.40	3.45

Session VI

Managing Soil Organic Matter

Session Chairs:

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Managing Soil Organic Matter to Enhance Soil Fertility

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INTRODUCTION

The management of soil organic matter is critical to maintaining a productive farming system. Soil organic matter (SOM) has been difficult to define analytically but can be conceptually divided into compartments relating to nutrient availability. The key to managing for available nutrients is to manage certain fractions of soil organic matter with a range of soil fertility amendments including crop residues, cover crops, manure and compost. The management of fertility amendments requires an understanding of their long-term influence on soil properties and fertility interaction among different amendments and inorganic fertilizers. The successful management may reduce the need for fertility inputs over time as a result of sustainable nutrient cycling and retention. Soils in temperate climates with higher clay contents generally have the most SOM. In the warmer and more arid California environment, where the decomposition of SOM limits its accrual in soil, agricultural soils average between 1 to 3% SOM. In general, intensive management to increase crop production has maintained SOM while in some cases increased SOM in California agriculture soils (De Clerck et al., 2003). These results indicate that management to increase SOM is feasible in the irrigated/arid climate of California.

Soil Organic Matter

Soil organic matter formation and decomposition are fundamental processes that both release and store the energy from plant inputs in soil. Soil organic matter is primarily the product of microbial and faunal decomposition of plant residues and root exudates. Plant residue decomposition leads to the formation of humic substances a potentially more stable form of SOM. When humic substances combined to interact with soil minerals such as clays, they become heavy in nature and constitute 70-80% of the organic matter in most soils. The more stable humic substances range in age from years to thousands of years. Humic substances require extraction in alkaline solutions to isolate from the mineral matrix. The remaining lighter portion of SOM is termed light fraction or particulate organic matter and is composed of recently deposited plant inputs undergoing various stages of decomposition. Some plant residues can become entombed within aggregates and thus protect them against degradation for many years. Light fraction is isolated from soil based on its buoyancy in a heavy liquid.

The structure and composition of SOM remains somewhat a mystery because of its complex chemical constituents and interaction with clay minerals. The lack of knowledge on SOM structure and function has made it difficult to understand its role in soil fertility. For this reason, SOM is often divided into conceptual compartments acting separately to contribute to the fertility of the soil (Paul and Clark 1996). Commonly conceptualized compartments are the active and passive fraction. The active fraction is labile and provides a source of readily mineralizable nutrients. It is composed of the plant residues, root exudation, light fraction, and the microbial biomass (Tisdall and Oades, 1982). The passive fraction is more responsible for imparting physical and chemical characteristics to soil. The influence of passive SOM on cation exchange capacity is dramatic and accounts for a substantial portion of the soils ability to retain nutrients. Both passive and active light fraction act to promote soil structure making it easier for plant roots to move through the soil and water to infiltrate the soil profile. The active fraction of SOM influences nutrient cycling to the greatest extent. The active fraction responds readily to management and changes in nutrient availability can often be realized within 1 to 3 years.

ORGANIC MATTER AS A NUTRIENT SOURCE

The formation of SOM promotes the capture of nutrients into its structure, especially the important nutrients nitrogen, phosphorus and sulfur. Soil organic matter is composed mainly of carbon (55%), 5 to 6 % N and 1% each of P and S. Because SOM contains C, it is an energy source for microorganisms, similar to fresh plant residue input. The decomposition of soil organic matter releases nutrients for plant uptake. Generally, 2 to 5 % of soil organic matter decomposes annually (Paul and Clark 1996). The amount of N mineralized often can meet the entire N need of a crop, however the timing of mineralization often does not coincide with crop need making fertilization necessary. The lack of synchrony between mineralization of soil N to crop need is a major challenge in agricultural systems and is especially true in organic systems that rely solely on nutrients from the turnover of SOM and the decomposition of organic inputs such as cover crops, compost and manure.

The quality of C and its interaction with minerals within SOM fractions affects the availability of nutrients by influencing decomposer activities. High C content of SOM fractions can often lead to microbial immobilization of nutrients through the production of biomass that requires additional N to grow (Horwath et al., 2002). The requirement for additional N to decompose poorer quality crop residue or cover crop directly competes for nutrients that crops could utilize. In addition to the biological competition for nutrients, the physical protection of SOM adsorbed to clay minerals slow decomposition processes that impact the availability of nutrients found in SOM. An indirect effect of SOM on nutrient availability includes soil physical property improvements that promote healthy plant growth allowing plants to capture more nutrients and facilitates water mediated nutrient movement to the roots. The key to promoting nutrient cycling is to enhance the turnover of the active fraction with inputs to influence its' size and composition.

MANAGEMENT OF SOIL ORGANIC MATTER

The management of SOM requires active inputs of crop residues and organic amendments to supplement loses through decomposer activities and uptake of nutrients by crop plants. The use of cover crops, both leguminous and cereal, composts and manure are traditional ways to maintain SOM and nutrients in organic systems. Manipulating the soil through tillage often can make nutrient more available but may negatively impact the accumulation of SOM.

Cover crops

Prior to the use of chemical fertilizers, cover cropping was often used to enhance soil fertility and tilth. The use of cover crops is an excellent way to increase the quality of soils through the addition of organic matter. Soil Quality is enhanced through the introduction of N through leguminous cover crops and reduction of nutrient transport from agricultural fields. As SOM builds up, equilibrium between carbon inputs and nutrient availability occur leading to sustained plant nutrient availability. The effect is primarily attributed to the accumulation of the light fraction and microbial biomass (Horwath et al. 2002).

Cover crop mixtures containing legumes can introduce up to 150 kg/ha in temperate climate cropping systems depending on cover crop species, plant density, and crop growth (Poudel et al. 2001). Cover crops also bioaccumulate significant amounts of phosphorous, potassium, and a range of micronutrients in organic form increasing their availability to crops in both space and time. The decomposition of cover crop leads to the mineralization of nutrients depending on the quality or C content of cover crop. Leguminous cover crops having up to 5% N produce low C to N ratio (less than 25) residue that is decomposed quickly leading to increased nutrient availability through enhanced mineralization. Within the first year following cover crop establishment only a small portion of the cover crop N will become available to the next crop. The N recovery rates in crops following legume cover crops range from 10 to over 50% of the cover crop N (Hadas et al 2002). The sustainable nutrient cycling benefit from accumulating SOM through the use of cover crops are realized within one to three years (Doane et al. 2003). Changes in soil tilth and water infiltration are often immediately realized after one or two years. The recovery of cover crop N by crops is dependent on environmental factors (e.g., climate, soil conditions), type of management (e.g., shredding, mixing, soil incorporation) and cover crop residue quality (e.g., C: N ratio, cellulose, lignin content).

Animal manures

The application of animal manure is an important tool for organic agriculture resulting in an increase in SOM levels, increased active fraction and supply nutrients for crop growth. Manures often contain a significant supply of ammonium and nitrate that are readily available to crops. The quality of manure, whether it's composted, fresh or aged has a great impact on the ability to supply nutrients and when the nutrients become available. Long-term application of manures can significantly improve SOM levels. For example, the biannual application of up to 4 to 6 t ha^{-1} of composted poultry manure for 10 years increased SOM by 3.0 t ha^{-1} compared to a conventionally managed system (Horwath et al., 2002). The degree to which animal manure applications affect SOM levels is highly variable and depends on the quality and nature of the manure.

Manures are generally more resistant to decomposition than plant residues since they are somewhat partially decomposed. For this reason, animal manures can be considered a slow release fertilizer source. The timing and method of manure application affect both SOM maintenance and nutrient availability. The application of manure should be done during periods of active decomposer activity and plant uptake, such as prior to planting. The application of manures during periods of low crop growth can result in significant amount of nutrients lost to leaching and erosion and gaseous N losses to the atmosphere. Loss of manure nutrients can be considerably minimized through soil incorporation.

Compost

The nutrient content of composts varies considerably depending of type of raw materials used, method of composting, and maturity. For this reason, nutrient mineralization rates from compost can vary widely. Compost applications can form the foundation of an effective nutrient and SOM management strategy. Nutrients in composts are generally less available compared to manures and in some cases leguminous cover crops. Composted manure, for example, releases N at a considerably slower rate than unprocessed manure. The primary reason for reduced nutrient availability in composts is the higher degree of decomposition leading to the production of humic substances resulting in a slower release of nutrients, especially N (Churchill et al. 1996).

The increase in stable SOM and favorable soil properties can be more effectively accomplished with compost than with fresh manure. The main reason for this is that compost is in an advanced state of decay. The increase SOM through compost additions can result in enhanced soil quality indicators. For example, (Joyce et al. 2002) showed that organic management with composts improved porosity and water retention. Biological soil quality indicators, such as biomass C and N are also improved with compost applications (Horwath et al. 2002). In the long term, however, the amount of organic matter applied is more important than the type of organic amendments used.

Tillage
Tillage plays an important role because of its influence on SOM quantity and dynamics. Tillage incorporates plant residues into the soil creating a mixing action that enhances microbial activity. The increased microbial activity leads to increased mineralization of C and nutrients. Type, frequency, and intensity of tillage determine the effect that tillage has on soil processes. Higher intensity and frequency of tillage results generally in lower SOM and nutrient retention. Absence of tillage tends to increase N mineralization capacity compared to tilled soil.

long-term benefits of accumulating SOM

The accumulation of SOM often leads to enhanced soil fertility through the sequestration of plant nutrients, especially N. The average annual N loss (applied – accounted in soil and crop) at SAFS in the organic treatment was 9 kg N ha^{-1} y^{-1} compared to 40 kg N ha^{-1} y^{-1} in the conventional rotation (Table 1).

Table 1. Soil N balance (30 cm soil depth) and loss for organic, low-input and conventional farming systems at the SAFS project 1988 to 1998 (modified from Poudel et al. 2001).

Cropping System	N balance (kg N ha^{-1})[1]	Soil N storage (kg N ha^{-1})[2]	N loss (kg N ha^{-1})[3]
Organic	991	901	90
Low-input	364	327	37
Conventional	488	79	409

1 N balance = Total N input- crop removal.
2 Soil N storage = Soil N 1998-soil N 1988.
3 N loss = N balance- soil N storage.

The cover cropped/reduced synthetic “low-input” rotation lost only 3.7 kg N ha^{-1} y^{-1}. These results show the value of cover crops in minimizing losses of N from both organic and synthetic sources. Drinkwater el al. (1998) showed similar results for row crop systems at the Rodale Institute in Pennsylvania. Overall, managing for increased soil organic matter greatly enhances the ability of soils to cycle nutrients sustainability, provides habitat for more soil organisms and creates a favorable environment for plants to exist.

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Residue Management, Soil Organic Matter and Fertility in California Rice Systems

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Abstract

Over the past 15 years, in-field residue incorporation has transitioned from a burning "alternative" to the primary means of residue management for California rice growers. As a result, the amount of organic matter in the soil has increased and nutrient availability has been altered. From long-term experiments, it is clear that available soil N is increased if residue incorporation and winter flooding are maintained for greater than 3 years; however, the impact on soil fertility in growers' fields, where management options are frequently rotated to reduce pest and weed pressure, is less certain. This paper will discuss the results of recent efforts to evaluate fertilizer use by rice growers and identify changes in fertility management following legislated reductions in straw burning.

Introduction

California rice yields are among the highest in the world, mainly due to ideal growing conditions and state-of-the-art equipment and management practices. However, growers are facing smaller returns and greater scrutiny over the environmental impact of production practices and the continued viability of rice production systems may depend upon refining management strategies to support high yields and maintain sustainable resource stewardship.

In 1991, the California Rice Straw Burning Reduction Act (AB1378) attempted to mitigate the negative impact of rice straw burning on air quality, and led to the adoption of alternative methods of straw disposal for much of the more than 500,000 acres of rice grown in the Sacramento Valley. Market demand for rice straw has been limited and off-farm disposal has not been economically viable for most growers. Consequently, in-field residue incorporation has transitioned from a burning "alternative" to the primary means of residue management despite uncertainty over the impact of straw incorporation on rice growth and yield (Hill, 1999).

When rice straw is incorporated, nutrients are retained in organic forms that are initially less available than those contained in the ash of burned fields; however, over time, straw incorporation results in a greater soil organic matter, microbial biomass and an increased potential for nutrient recycling (Bird, 2001). Soil organic N is the largest source of plant available N for rice, providing from 50% to 80% of total N taken up by the crop (Mikkelsen, 1987), suggesting that changes in residue management can have major impacts on fertility and production. As a result, it has been necessary to reevaluate fertilization practices in rice.

In 2003 and 2004, we conducted a comprehensive evaluation of the impact of rice straw management on nutrient cycling throughout the Sacramento Valley. Our evaluation included grower surveys and trials in grower managed fields throughout the Sacramento Valley. The results suggest that straw management practices can significantly impact nutrient availability and should be taken into consideration when designing fertility management programs.

Objective

To evaluate current fertilizer use by growers and identify changes in fertility management following legislated reductions in straw burning.

Grower Survey

Participants of the 2003 UCCE Annual Rice Growers' Meetings were asked to complete a survey of their fertility management practices. A total of 106 surveys were completed of the 260 handed out, accounting for 72,527 acres of rice grown in the Sacramento Valley in 2002.

Highlighted results:

- There is no clear consensus on the impact of straw management on fertilizer practices among growers. 52% of growers have not altered their fertilizer practices following changes in straw management; 29% decreased fertilizer rates (10 lbs N / ac average); 9% increased fertilizer applications to combat N tie-up; 6% specified that they had changed rates but did not specify in which direction; and 4% did not respond.
- Fertilizer rates: Growers report using a variety of methods to determine fertilizer application rates. 86% of growers cited previous experience; 53% soil tests; 26% outside recommendations; 7% tissue samples; and 7% color charts.
- Straw management: 80% of the acreage had field residues incorporated, 14% burned and 6% baled and removed.
- Winter flooding: 83% of growers practice winter flooding in some portion of their fields. 48% of acreage subject to continuous flooding, 9% of acreage is flash flooded.

The complete results are available at UCCE Rice web site:
http://agronomy.ucdavis.edu/uccerice/NEWS/FertilityMgtSurvey2003.pdf

Field Trials

In 2003, we began a comprehensive evaluation of the overall fertility status in rice growers' fields as impacted by straw management practices. Over the past 2 years, N-rate fertility trials were conducted with 25 growers in 75 fields located throughout the Sacramento Valley. The trials included extensive soil and plant sampling and monitoring of three different N rates across a variety of soils, under a variety of management practices.[6] In addition, all sites were examined for macronutrients N, P, K, Ca, and Mg, and micronutrients Na, Fe, Cu, Zn and Mn.

Yield data were collected from small plot harvests and were grouped by management history for the purpose of analysis. The results indicate that midseason plant indicators including color, height, vigor, and tissue N levels significantly increased with increasing pre-plant N fertilizer application rates. In 2003, there was an apparent overall trend of yield increasing with N-rate, although it was not significant (P=0.14). However, when three year field histories were used to group the data for analysis, a comparison of relative yields within fields indicated that those fields with a history of residue incorporation had significantly greater yields under the reduced fertilizer treatment than those where residue was burned or baled (P=0.03). The results suggest that straw management practices can significantly impact nutrient availability and should be taken into consideration when designing fertilizer programs.

Research Directions

We are currently in the process of undertaking a more complete analysis of the results, including identifying regional fertility trends, correlating overall fertility status with management practices, and the development of specific fertility management recommendations for growers.

To that end, in 2005 we will continue our current N-rate trials in grower managed fields and expand the scope to include starter fertilizer materials with additional nutrients, focusing on timing of application and rate response treatments.

[1] All rate manipulations were made to pre-plant fertilizer applications. The N rates were based upon grower standard practice for a given field, and included a 25% or 25 lb N ac^{-1} decrease in pre-plant N, standard practice, and a 25 % or 25 lb N ac^{-1} increase in pre-plant N.

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Wood Chipping Almond Brush and Its Effect On Soil and Petiole Nutrients, Soil Aggregation, Water Infiltration, and Nematode and Basidiomycete Populations

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SUMMARY - The wood chipping of almond prunings in California, instead of burning, can reduce air pollution and return organic matter to soils. The success of wood chipping depends on whether the chips do not deplete critical nutrients necessary for tree growth. An experiment was established where soil was mixed with or without wood chips and placed in containers, each with an almond tree. There were more free-living nematodes in the chipped soils when compared to non-chipped soils. More basidiomycetes were counted in wood chipped soils and detected at higher levels with ELISA. Larger soil aggregates were found in wood chipped soils. Undisturbed wood chipped soils had more soil aggregates than disturbed soils. After the first year trees growing with wood chips had less shoot growth, but by the second year trees with wood chips had more shoot growth. Soil analysis after two years showed higher levels of calcium, magnesium, sodium, boron, zinc, copper, carbon, phosphorus, potassium, ammonium, and % organic matter in wood chipped soils. There was less manganese, iron, and nitrate in the wood chipped soils and the pH was reduced. Tissue analysis was performed on leaf petioles. After the first year trees growing with wood chips had less nitrogen, zinc, and manganese, while phosphorus was increased. After the second season trees with wood chips no longer had less nutrient levels while phosphorus was still increased. Water infiltration was significantly greater in wood chipped soils all three years.

Keywords: *Prunus dulcis*, free-living nematodes, soil aggregating basidiomycetes, petiole and soil nutrients

INTRODUCTION

The San Joaquin Valley (SJV) Unified Air Pollution Control District restricts the burning of agricultural wastes and further restrictions are likely due to worsening air pollution. Since the passing of The Federal Clean Air Act Amendments of 1990 the SJV of California has not met national ambient air quality standards for particulate matter 10 microns (PM-10) or less. The wood chipping or shredding of almond prunings could provide an alternative to burning that can add valuable organic matter to SJV soils typically low in organic matter. A small percentage of almond growers have been chipping or shredding their purnings for over 14 years; some because they are farming on the agricultural-urban interface where brush burning is prohibited because of its close proximity to housing. Other almond growers have chipped or shredded their prunings solely to add organic matter to their soils. But many growers fear that wood chips or shreddings will take valuable nutrients away from their trees (Holtz, 1999). If wood chips can be shown not to interfere with harvest or take valuable nutrients from trees, then growers would be more likely to adopt chipping or shredding as an alternative to burning.

Research has shown that organic material can increase the humic content of soil (Sikora and Stott, 1996), the nutrient holding capacity of soils (Gaskell *et al*., 2000, Hartz *et al*., 2000), and the cation-exchange-capacity (Fox *et al*., 1990), which is a measure of the ability of soil to hold nutrients. Soil organic matter has also been shown to increase the water holding capacity of soil, the pH buffering capacity, the microbial diversity of soils (Scow *et al*., 1994), and to even reduce plant parasitic nematode populations (Leary and DeFrank, 2000). Saprophytic lignin-decomposing basidiomycetes have been shown to produce large quantities of extracellular materials that bind soil particles into aggregates (Caesar-TonThat and Cochran, 2000). The effect of wood chips on soil and petiole nutrients, soil aggregation, water infiltration, and nematode and basidiomycete populations was initiated in a replicated experiment where soil was amended with and without wood chips (Holtz and McKenry, 2001). If results were available to growers that show enhanced nutrient value due to wood chipping, it would speed adoption of the practice and help reduce air pollution in the SJV. There are over 250,000 hectares of almonds in California, and burning is still the primary method of brush disposal.

MATERIALS AND METHODS

Wood chipping, tree placement, and water infiltration - Almond prunings were chipped with a brush bandit wood chipper (Bandit Industries, Remus, MI). The wood chips were mixed with Tujunga loamy sand high in ring (*Macroposthonia* spp.) and root lesion (*Paratylenchus* spp.) plant pathogenic nematode populations taken from almond orchard soil (L.D. James Ranch, Modesto, CA). The wood chips were mixed with soil at approximately 1/3 part wood chips to 2/3 parts soil, and placed in 133 liter barrels (Monsanto, St. Louis, MO), with a single 1-year old bare root 'Nonpareil' almond tree per barrel. Five trees each were planted in barrels with and without wood chips. The barrels were placed in an almond orchard in a replicated manner, consisting of five single-tree replicates per treatment. The barrels prevented the mixing of roots, wood chips, and microbial communities and allowed placement of a replicated trial in a small area. Trees were not fertilized but were irrigated twice weekly with a drip irrigation system from ground water. The time in seconds for 18.9 liters (5 gallons) of water to infiltrate soil amended with and without wood chips was measured on four occasions.

Leaf, shoot growth, and soil sampling – Fifty - 75 leaves were collected randomly from non-fruiting spurs from each tree in July of 2000, 2001, and 2002. One kg of soil was removed from just under the surface of each barrel in October of 2000, 2001, and 2002. Half of each sample was assayed for nematodes while the other half was analyzed for nutrients. Leaf and soil samples were analyzed for mineral content by the University of California's Division of Agriculture and Natural Resources (DANR) Laboratory (Davis, CA). Current season shoot growth was measured (cm) in May of 2000, 2001, and 2002. The five longest shoots per tree were selected and measured.

Nematode and basidiomycete sampling - Ring nematode was assayed with the sugar centrifugation method (McKenry and Roberts, 1985) where 1-2 kg of soil is placed into a pan with water and mixed. Nematodes were suspended in water and decanted. A 1-molar solution of sugar plus separan was added to a cylinder and stirred. After 1 minute the nematode-soil separation was passed through a 400-mesh screen. With a small quantity of water, the nematodes were washed from the screen into a counting dish. Nematodes per 1 kg of soil (250 cc) were reported. Root lesion and free-living nematodes were extracted by a combined sieve-mist extraction method where the final screenings from a 500-mesh sieve containing 20 grams of root plant tissues were placed into a funnel and then into a mist chamber. After 3-5 days the nematodes were removed and counted. Basidiomycetes were counted in plots (mushrooms/barrel) when they appeared, usually after January and February winter rainfall.

Orchard soil sampling and separation of soil aggregates - In January 2001, Tujunga loamy sand soils were sampled from a 30 year-old almond orchard where prunings were chipped and left on the orchard floor annually for 14 years. Soil samples were collected from 2 treatment sites: 1) where the orchard floor soil had been left undisturbed, and 2) where the orchard floor soil was disturbed prior to harvest (August 2000) with a rotary-tiller (Maschio, Padova, Italy) to a depth of 12-15 cm. Soil samples were collected from three areas in each site. At each site three soil cores were taken to a depth of 18 cm using a step-down soil probe and divided into increments of 0-to-3, 3-to-8, 8-to-13, and 13-to-18 cm. The three samples at each depth were mixed to form a composite sample. Samples were collected using a stratified sampling scheme so that within-row and between-row areas of the plots comprised the proper proportion of the composite sample (Caesar-TonThat *et al.*, 2000). Soils were dried in a forced-air oven at 50^{o}C and then passed through a series of sieves (>2mm, 0.84mm, 0.42mm, and 0.25mm-mesh).

Enzyme Linked Immunosorbent Assay (ELISA) - Presence of soil aggregating basidiomycetes was determined for each soil aggregate size fraction using Enzyme Linked Immunosorbent Assay (ELISA) (Caesar-TonThat *et al.*, 2001). Dry soil samples (500 mg/ml) were prepared by homogenization of samples in a mortar and pestle in carbonate buffer (20 mM $NaHCO_3$, 28 mM Na_2CO_3, pH 9.6), and a dilution series (1.17 to 75 mg/ml) was prepared in this buffer. Homogenates were centrifuged for 10 min (14,000 *g*) after which 100 µl of the supernatant was loaded in flat bottom microtiter plate wells (Immulon 4HBX, Dynex Technologies Inc., Chantilly, VA) followed by incubation overnight at 55°C. After three washings with 0.01M phosphate buffer saline-Tween 20, 0.138 M NaCl, 2.7 mM KCl, pH 7.4 (PBST, Sigma, St Louis, MO), 100 µl of a 1/10,000 dilution of the third boost rabbit serum was added to each well. Microtiter plates were incubated for 90 min at 22°C on an orbital shaker, washed 3× with PBST, and incubated for 60 min at 22°C with a 1/13,000 dilution of horseradish peroxidase-conjugated goat anti-rabbit polyspecific immunoglobulins (Sigma, St Louis, MO) added to each well. After three further PBST washings, the substrate, consisting of a solution of 3,3', 5,5' tetramethylbenzidine (0.4 g/l) (Pierce, Rockford, IL) and 0.02% hydrogen peroxide, was added. The reaction was stopped after 30 min with 2.5 M sulfuric acid. Absorbance was read at dual wavelength of 450 nm/655 nm using a BioRad 550 microplate reader, controlled by a computer using the Plate Reader Manage program (BioRad, Hercules, CA). All incubation steps were performed at room temperature. All samples were processed in triplicate.

RESULTS AND DISCUSSION

Leaf petiole analysis and shoot growth - Leaf petiole analysis showed that trees growing in soil amended with wood chips had significantly less nitrogen (N) in 2000, reduced levels in 2001, and higher levels in 2002 (Table 1). Phosphorus (P) increased significantly in trees growing in soil amended with wood chips all three years. Potassium (K) was significantly increased in trees grown with wood chips in both 2001 and 2002. Calcium (Ca) and boron (B) levels increased significantly in trees grown with wood chips in 2002. Zinc (Zn) and manganese (Mn) levels decreased significantly in trees grown in soil amended with wood chips. Sodium (Na) and magnesium (Mg) levels were unaffected by the addition of wood chips. Trees growing in soil amended with wood chips and significantly less current season shoot growth in 2000 and 2001 when compared to trees growing in soil without wood chips, but by 2002 and 2003 the growing in soil with wood chips had significantly more shoot growth (Figure 1).

Soil analysis and water infiltration rate - Soil analysis showed that the addition of wood chips significantly increased soil electrical conductivity (EC), Ca, Mg, Na, Cl, Zn, copper (Cu), P, K, ammonia (NH_4-N), carbon total (C-Tot %), and percent organic matter (OM %) (Table 2). Boron (B) levels were significantly higher in soil amended with wood chips in 2001. The cation-exchange-capacity (CEC) was higher in wood chip amended soil in only 2000. The addition of wood chips significantly lowered soil pH all three years. Nitrate levels (NO_3-N) were significantly lowered by the addition of wood chips in 2000 and 2001, but by 2002 nitrate levels in wood chipped soils were actually higher than in non-wood chip amended soils. Manganese (Mn) and iron (Fe) levels were initially lowered by the addition of wood chips in 2001, but by 2002 their levels with were significantly increased (Table 2). The rate at which 18.9 liters (5 gallons) of water infiltrated soil amended with and without wood chips was measured on four occasions. In soils amended with wood chips we observed significantly faster water infiltration times when compared to soils not amended with wood chips (Figure 2).

Nematode and basidiomycete sampling - The effect of wood chips in soil on plant parasitic and free-living nematode populations were examined. In 2000, *Macroposthonia* (ring) populations were significantly reduced while *Bunonema* and *Dorylaimida* and free-living nematode populations were significantly increased in wood chip amended soils (Table 3). In 2001 and 2002 *Macroposthonia* (ring) populations were lower while *Paratylenchus* (root lesion) species were significantly reduced in wood chip amended soils. Free-living bacterial and fungal feeding nematodes were significantly increased in wood chip amended soils (Table 3). In 2001 and 2002 *Bunonema, Trichodorus, Dorylaimida*, and *Monochida* species appeared unaffected by the addition of wood chips to soil. The effect of wood chips in soil on basidiomycete populations was also examined. Basidiomycetes were only found in soils amended with wood chips, averaging 5.8 mushrooms per barrel. Basidiomycetes were never found in plots without wood chips.

Soil aggregation - There were significantly more soil aggregates >2 mm in all the layers (0-3 cm, 3-8 cm, 8-13 cm, and 13-18 cm) of undisturbed soils amended with wood chips than in disturbed soils also amended with wood chips (Figure 3). In layer 1 (0-3 cm), 63.2 % of >2 mm soil aggregates were in undisturbed soils compared to 36.43 % in disturbed soils. In layer 2 (3-8 cm), 69.10 % compared to 16.80 %, and in layer 3 (8-13 cm), 80.87 % compared to 30.10 %. In layer 1, the size fractions smaller than 2 mm aggregates were higher in soils from the disturbed compared to the undisturbed site, except for the 0.8-2 mm size-fraction, which is significantly higher in the undisturbed soils. In all soil layers, undisturbed soils amended with wood chips contained significantly greater amount of >2 mm aggregates when compared to the other size fractions. In contrast there was no significant differences among the aggregate size fractions in disturbed soils amended with wood chips.

ELISA - The same size fractionated soil samples from undisturbed and disturbed sites amended with wood chips were analyzed using ELISA to detect and quantify populations of specific soil aggregating basidiomycete fungi (Figure 4). Results showed a greater response to antibodies in soils from undisturbed sites when compared to disturbed sites in the four soil layers. In the surface soil layer, the amount of soil-aggregating fungi was significantly greater in the undisturbed soils when compared to the disturbed soils, and a greater response to the antibodies was observed in the >2 mm and 2-0.84 mm aggregate size fractions. In the other deeper layers, no differences in populations of these fungi were detected.

CONCLUSIONS

The addition of wood chipped prunings to soil planted with almond trees initially reduced leaf petiole and soil nitrate levels in the first year, but by the second year leaf petiole levels were no longer significantly less, and by the third year both leaf petiole and soil nitrate levels were higher in leaves and soils from trees grown in wood chip amended soils. Most nutrients by the third year were significantly higher in soil amended with wood chips or leaf petioles from trees grown in wood chip amended soils. This data was supported by greater current season shoot growth from trees grown in wood chip amended soils in the third and fourth seasons, providing evidence that even though wood chips initially tied up nitrogen when first added to the soil, as they decomposed the wood chips eventually returned more nutrients to soils amended with wood chips when compared to soils not amended with wood chips.

The addition of wood chips significantly lowered soil pH all three years, while soil carbon and soil organic matter was increased. Water infiltrated wood chip amended soil much more quickly when compared to soils without wood chips, presumably due to greater pore spaces due to the additional organic matter. The wood chips also appear to be reducing ring and root lesion pathogenic nematodes while increasing free-living bacterial and fungal feeding (non-pathogenic) nematodes. More basidiomycete fungi were counted in soils amended with wood chips, and soil-aggregating basiciomycetes were detected at higher levels with ELISA. Larger soil aggregates were found in wood chipped and undisturbed soils. The addition of wood chipped almond prunings to soils appear to be enhancing soil nutrient levels, basidiomycete wood rotting and soil aggregating fungi, and free-living nematode populations while providing almonds growers with a more sustainable method of brush removal.

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Table 1. Leaf petioles were sampled in July in 2000, 2001, and 2002 from trees growing in soil amended with and without (no-chips) wood chips and analyzed for the following nutrients

	2000		2001		2002	
	Wood chips	No-chips	Wood chips	No-chips	Wood chips	No-chips
% N	1.55 a*	2.21 b	1.38 a	1.58 a	1.92 a	1.6 a
% P	0.33 a	0.18 b	0.96 a	0.31 b	0.66 a	0.43 b
% K	2.69 a	2.67 a	2.47 a	2.01 b	1.92 a	1.62 b
% Na	0.02 a	0.02 a	0.02 a	0.01 a	0.02 a	0.02 a
% CA	1.63 a	1.62 a	2.69 a	2.48 a	3.04 a	2.76 b
% Mg	0.5 a	0.39 a	0.78 a	0.86 a	0.7 a	0.74 a
Zn ppm	41 a	88 b	53 a	63.23 b	10.0 a	6.5 b
Mn ppm	163 a	245.66 b	93.75 a	90.75 a	18.4 a	48.4 b
B ppm	51 a	50.66 a	47.5 a	43.5 a	45.6 a	37 b
Fe ppm	196 a	183 a	323.5 a	292.5 a	54.0 a	57.4 a
Cu ppm	11.66 a	9.33 a	16.75 a	17 a	4.4 a	4.0 a

*Paired columns within the same year with different letters were statistically different when compared in a Student's T-test (P # 0.05)

Table 2. Soil samples were taken in October 2000, 2001, and 2002 from trees growing in soil with and without (no-chips) wood chips and analyzed for the following nutrients

	2000		2001		2002	
	Wood chips	No-chips	Wood chips	No-chips	Wood chips	No-chips
pH	6.5 a*	7.2 b	6.7 a	7.5 b	6.88 a	7.38 b
EC mmhos/cm	0.5 a	0.3 b	0.5 a	0.3 b	0.48 a	0.29 b
Ca meq/L	2.8 a	1.2 b	2.8 a	1.4 b	3.20 a	1.47 b
Mg meq/L	1.6 a	0.8 b	1.6 a	1 b	1.97 a	0.98 b
Na meq/L	0.90 a	1.00 a	1.5 a	1.1 b	0.93 a	0.62 b
Cl meq/L	0.50 a	0.50 a	0.60 a	0.60 a	1.15 a	0.48 b
B ppm	0.50 a	0.60 a	0.8 a	0.5 b	----**	----
Zn ppm	12.2 a	4.7 b	5.7 a	3.2 b	6.80 a	3.58 b
Mn ppm	34.30 a	34.70 a	8.7 a	25.4 b	7.98 a	3.37 b
Fe ppm	176.40 a	122.00 a	18.6 a	67.5 b	16.88 a	10.17 b
Cu ppm	8.4 a	3.8 b	4.1 a	2.4 b	4.98 a	2.73 b
C-Tot %	6.6 a	0.4 b	1.0 a	0.4 b	1.09 a	0.40 b
NH4-Nppm	10.7 a	3.1 b	6.8 a	2.7 b	8.78 a	2.75 b
N03-N ppm	0.7 a	2.2 b	0.1 a	0.6 b	0.65 a	0.32 a
Bray P ppm	56.9 a	46.3 b	46.9 a	24.2 b	39.62 a	17.55 b
X-K ppm	114.4 a	49 b	94.2 a	55.8 b	54.17 a	36.50 b
CEC meq/100g	9.0 a	5.9 b	3.90 a	3.40 a	6.83 a	4.52 b
OM %	6.4 a	0.5 b	1.2 a	0.4 b	1.36 a	0.50 b

*Paired columns within the same year with different letters were statistically different when compared in a Student's T-test (P # 0.05)
**---- data was unavailable

Table 3. One kg soil samples were taken in 2000, 2001, and 2002 from soil amended with and without wood chips and assayed for the following nematodes

	2000		2001		2002	
	Wood chips	No chips	Wood chips	No chips	Wood chips	No chips
Macroposthonia spp.	15.4 a*	53 b	298 a	392 a	545 a	399.6 a
Bunonema spp.	40.8 a	0 b	0 a	0 a	0 a	0 a
Trichodorus spp.	0 a	6.6 a	0 a	0 a	0 a	0 a
Dorylaimida spp.	159.4 a	19.6 b	2.2 a	36.2 a	47.4 a	38.6 a
Monochida spp.	0 a	0.4 a	0 a	0 a	55 a	59.4 a
Paratylenchus spp.	0 a	1.8 a	0 a	138.8 b	24.4 a	255 b
Free-living spp.	1307.2 a	690.4 b	1703.4 a	246 b	1006.4 a	437.4 b
Bacterial Feeding spp.	987.2 a	612 b	1371.3 a	223.3 b	872.128 a	394.1 b
Fungal Feeding spp.	320 a	78.4 b	332.1 a	22.7 b	134.272 a	43.4 b

*Paired columns within the same year with different letters were statistically different when compared in a Student's T-test (P # 0.05)

Figures

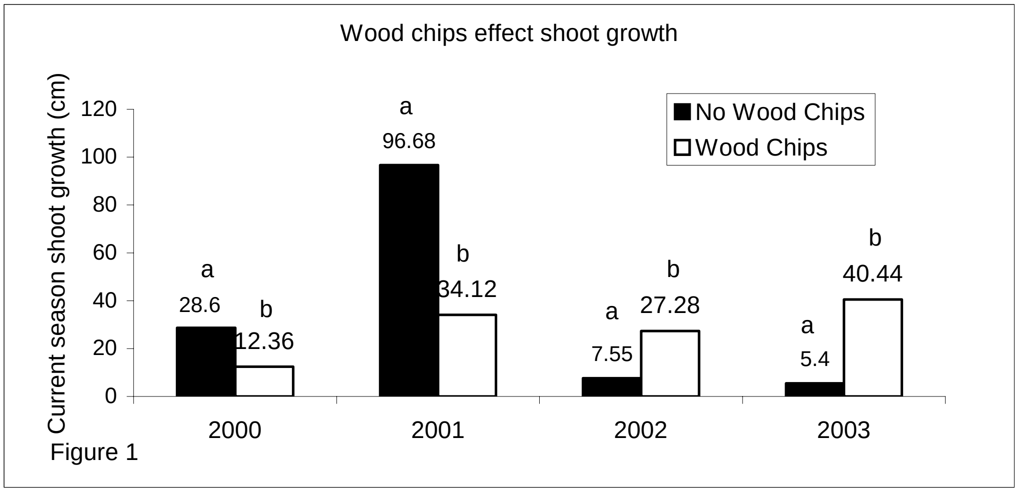

Fig. 1 Ten trees were planted in soil amended with wood chips and another ten trees in soil without wood chips. The five longest shoots per tree were selected and measured. Paired columns within the same year with different letters were statistically different when compared in a Student's T-test (P # 0.05).

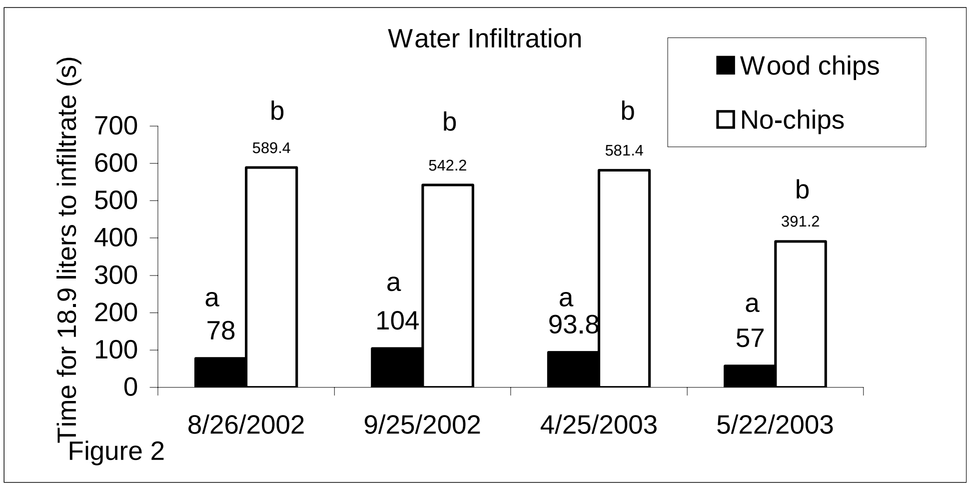

Fig. 2. The time in seconds (s) for 18.9 liters (5 gallons) of water to infiltrate soil amended with and without wood chips was measured on four occasions. Paired columns on the same day with different letters were statistically different when compared in a Student's T-test (P # 0.05).

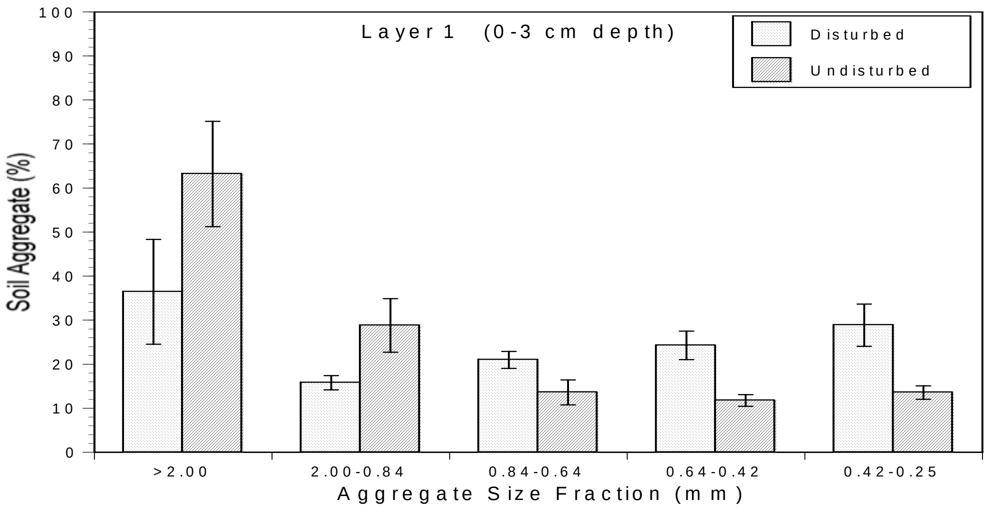

Fig. 3. Soils were sampled from disturbed (with a rotary-tiller) and undisturbed plots from and almond orchard where wood chipped prunings were added seasonally for 14 years. Soils were obtained from four debts with layer 1 (0-3 cm) shown here. Soils were dried in a forced-air oven at 50°C and then passed through a series of sieves (>2mm, 0.84mm, 0.42mm, and 0.25mm-mesh) in order to collect soil aggregates.

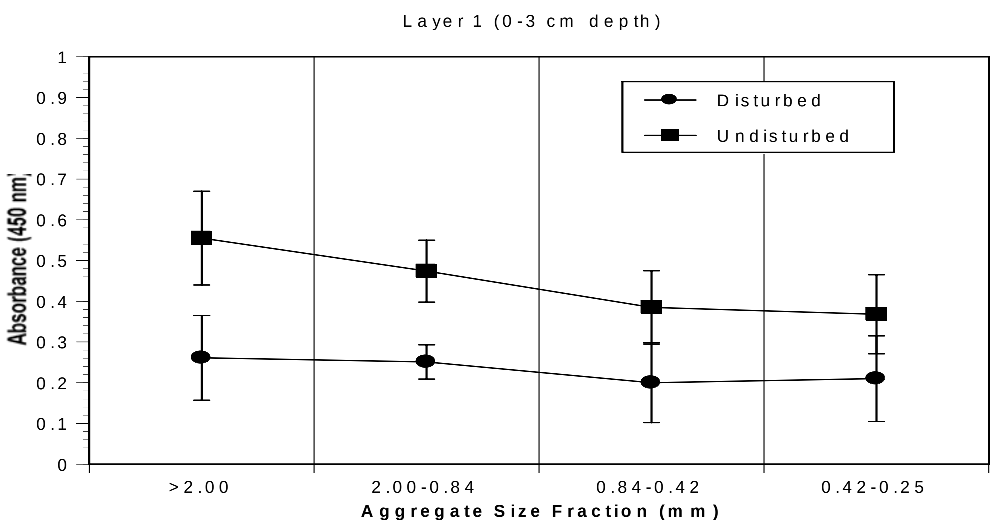

Fig. 4. Presence of soil aggregating basidiomycetes was determined for each soil aggregate size fraction using ELISA by quantifying the response to antibodies in soil. The same size fractionated soil samples from undisturbed and disturbed sites amended with wood chips were analyzed using ELISA to detect and quantify populations of specific soil aggregating basidiomycete fungi. Absorbance was read at dual wavelength of 450 nm.

Cotton Management Impacts on Soil Organic Matter

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Introduction

Since the early 1960s, science has driven the policy of crop residue management and indirectly the practice of applying organic matter inputs to California's San Joaquin Valley (SJV) cotton. The science behind current conventional practices is based on addressing specific pest control practices (insect and weeds). Historically, the primary focus of soil management for cotton production includes creating a good seed bed, weed control, water management and meeting the seasonal nutrient requirements for the crop. Options that directly impact soil organic matter levels include crop rotations, using animal manures or planting winter cover crops, which are weighed against the economics of alternative options. Specific attention to soil organic matter levels are acknowledged, but are often considered of secondary importance. Economic factors drive most farm decisions; however, as new emphasis is placed on soil organic matter through government programs, science will play a greater role in defining management practices for efficient cotton production and strategies to sustain soil productivity.

SJV Practices

The most influential policy affecting post-harvest management practices is the cotton plow down requirements. The stalk destruction and plow down requirements following harvest to suppress pink bollworm (Pectinophora gossypiella) establishment dictates fall management practices for SJV cotton. The science behind California's/six-county district plow down regulation is based on maintaining a 90-day host-free period to prevent successful over-wintering of pink bollworm larvae (Rudig, 2004). This policy prescribes the required shredding, undercutting and tillage practices recommended for optimum incorporation to ensure rapid residue decomposition (Johnson-Hake et al. 1996). In 2003, a reduced tillage permit was issued that permits post-harvest cotton residues of shredded stalks, root stubs and other plant debris to remain on the field surface. This closely monitored permit opens the opportunity to alter post-harvest field practices for SJV cotton residue management.

Cotton post-harvest management practices evolved around this late season window of opportunity. For example, fall additions of animal manure, soil amendments and fertilizers are applied after shredding stalks but before disking in residue. This provides an opportune time for addressing soil fertility needs and incorporating additional inputs for the following crop. Final tillage operations also allow the application of fallow-bed herbicide applications.

It is important to note that most states of the cotton belt follow similar practices in the management of cotton residues. This is not the case, however in developing countries. For example in Peru and

China farmers do not have the mechanical ability to shred and incorporate cotton residue. Instead stalks are collected and burned. In China, cotton stalks are an important domestic fuel source. This practice prevents the recycling of major plant nutrients back into the soil and contributes to nutrient depletion and the degradation of soils.

End-of-season management requirements also limit the early planting of winter cover crops in the SJV. Field trials conducted in the 1980s showed some positive benefits from a mini-rotation with barley cover crop planted in late November and incorporated in March, prior to pre-irrigation for the next cotton crop. A 10 percent increase in lint yields was observed in the first year from the barley cover crop due to a wet fall and good cover crop growth. However, results over the three-year study did not show significant differences between the cover crop and fallow treatments (Weir et al. 1987). The variation in fall precipitation makes the reliance on winter cover crops risky in the SJV. In the cited study, there was only one year out of the three studied with enough growth from a December planting of barley to produce a cover crop that provided a measurable benefit. In four out of the past five years, a pre-irrigation or early December irrigation would have been necessary to establish a cover crop following cotton in the Southern SJV. Mitchell et al (1999) provided a good review of the estimated water use for different winter cover crops. However, cover crop water use in not an issue if there is not enough early precipitation to establish a winter cover crop. Additionally, cotton fields are pre-irrigated prior to planting to refill the soil profile. The greater risks are from planting late and not having enough precipitation to minimize the production cost of growing a green manure cover crop. A wet spring could also delay managing the cover crop for timely cotton planting.

Seedbed preparation is considered one of the most important field operations to ensure a uniform stand of cotton. This practice is being reevaluated as the adaptation of new equipment in conservation tillage research shows increasing benefits. One important aspect of cotton stalk and residue management practices is considering the following crop. The shredding and plow down incorporation of residue is critical when following cotton with a small seeded vegetable crop. The planting of onions, broccoli, tomatoes and even melons can be problematic without proper attention to managing previous crop residue.

Cultivation and tillage are management practices that work against the build up of soil organic matter (Carter, 1996 and Horwath 2005). Post-plant tillage practices employed in SJV cotton are predominantly for early weed control and for channeling water for surface irrigation. The availability of herbicide tolerant upland cotton varieties has reduced the dependence on early cultivations, but this technology does not eliminate the need to create furrows for many surface irrigated soils. So while tillage can be reduced in some cotton systems, there are many soil types dependent on early season tillage for water management.

Row crop rotations in the SJV have changed over the past 15 years. In areas of the SJV some of the traditional agronomic crops used in the past as standard rotation options are no longer being planted. Acreage reductions in cereals, seed and oil crops have forced changes in long-standing cropping rotations. As a result, new commodities are entering the rotation cycle on open crop land. Since crops vary greatly in the amounts of organic matter contributions, changing rotations will influence the dynamics of soil organic matter in SJV soils. Crop biomass residue varies between nearly 9,500 pounds of corn stubble per acre to less than 1000 pounds for alliums (Mitchell et al. 1999). Above ground biomass of cotton can vary from 6,000 to 12,000 pounds per acre and would represent approximately 4,000 to 8,000 pounds of dry matter residue from lint yields of two to four bales per acre, respectively. The difference in cotton biomass residues returned to the soil can be significantly influenced by yield potential and management factors (Cassman et al.,1992, and Fritschi et al. 2003).

Importance of Soil Organic Matter

The "Old Rotation" is the oldest continuous cotton experiment in the world (circa 1896). Located at Auburn, Alabama, the "Old Rotation" mirrors other U.S. long-term experiments such as the Morrow Plots (Illinois, cf. 1876) and the Sanborn Field (Missouri, cf. 1888). These studies are important to follow changes in crop yields, soil carbon and nitrogen from agronomic practices and nutrient inputs over time (Mitchell and Entry, 1998). In Alabama's Ultisols, characterized as highly weathered, low organic matter, acidic soils, soil organic matter, as it contributes to soil carbon and nitrogen, is positively correlated to cotton yields under non-irrigated conditions (Mitchell and Entry 1998). In non-irrigated soils, the influence of soil organic matter on water holding capacity could provide an advantage equal to a nutritional factor (Horwath, 2005). Results from the "Old Rotation" have also documented the importance of management practices and crop rotations in maintaining soil organic matter levels under conventionally tilled cotton.

Research conducted in California by Cassman et al. (1992) showed a significant increase in soil organic matter and fiber yields in a continuous cotton rotation from the addition of fertilizer potassium or composted manure. Manure additions for two seasons resulted in an eight percent increase in soil organic carbon in the surface soil compared with the levels measured at the beginning of the study. During the same period, there was an 11 percent decrease in soil organic carbon and (NH_4Cl) extractable potassium in the unfertilized control plots. This work contradict the supposition that intensive management of tillage and irrigation and the semiarid environment of the SJV would not be expected to show an increase in soil organic matter or improvement in soil productivity (Andrews et al. 2002).

Organic matter contributes to seasonal cotton nutrient uptake. Cotton stalks are more resilient to decomposition than other crop residues. This is in part due to high C/N ratios and a higher percentage of hemicellulose and lignin compared to cellulose contents of other crop residues (Table 1) (Fox et al. 1990 and Fritschi et al. 2005). Fritschi et al (2005) studied the contribution of nitrogen derived from cotton residues to following cotton crops. The study showed approximately 4.5 percent of the N incorporated as aboveground residue was found in the shoot portions of the next cotton crop, which resulted in a contribution of only about 2.3 percent to the total N assimilated in that crop. While this contribution seems low, depending on the time of availability, it could make a significant difference in the seasonal N use efficiency of the following crop.

Table 1. Characteristics of cotton residue. (Fritschi et al. 2005)

	C/N	C	N	Cellulose	Hemicellulose	Lignin	Minerals
		-------	-------	------- g kg^{-1} -------	-------	-------	-------
Cotton residues	40.4	362.4	8.96	27.1	272.1	129.9	107.5

In addition to being resilient, cotton stalks decompose at different rates in different soils (Roberts et al. 2000). N mineralization rates of cotton residues for a Panoche and a Wasco soil are presented in Figure 1. The mineralization potential, for both low and high temperatures of the Wasco sandy loam represents a significant difference in available N. Preliminary data also suggests that different organic matter fractions maybe produced by specific microbial decomposition. Differences in organic matter fractions as shown in Figure 2, support the plausibility that microbial activity could influence the organic fraction ratios found in soils and the availability of labile soil organic N pools (Gonzalez-Vila et al., 2001).

Replacement Cost of Cotton Residue

In the late 1980s a proposal was debated on using cotton stalks as a fuel source for cogeneration plants burning agriculture biomass. Figures based on energy returns, were suggested to pay farmers $2.50 -$3.00 per ton for cotton stalks delivered to the cogeneration facilities. A conservative stalk yield of four tons per acre represented an additional return of $10 – $12 per acre. However, a UC Cooperative Extension newsletter (Meyer and Vargas, 1990) was written to point out that $3.00 per ton did not cover the cost of micronutrients recycled via residue decomposition. Adding the replacement cost of nitrogen, phosphorus and potassium increased the value of field recycling cotton stalks compared to supplementing the removal of these major nutrients.

Summary

Soil organic matter levels will become more important to future fertilizer recommendations once we gain a fuller understanding of the role organic matter plays in nutrient availability in cotton production. Management strategies need to be developed and encouraged through government support programs that target organic matter increases as agronomic goals, in addition to optimizing crop productivity. The role cotton production will have in overall carbon sequestration from crop production is a question that needs to be further explored. A common goal will be to enhance the in field cycling of nutrients to synchronize the mineralization of plant residues and labile soil organic matter with the seasonal crop needs for major and minor plant nutrients. Applying these goals to the management of soil biology will create opportunities to improve nutrient use efficiencies and sustain soil quality.

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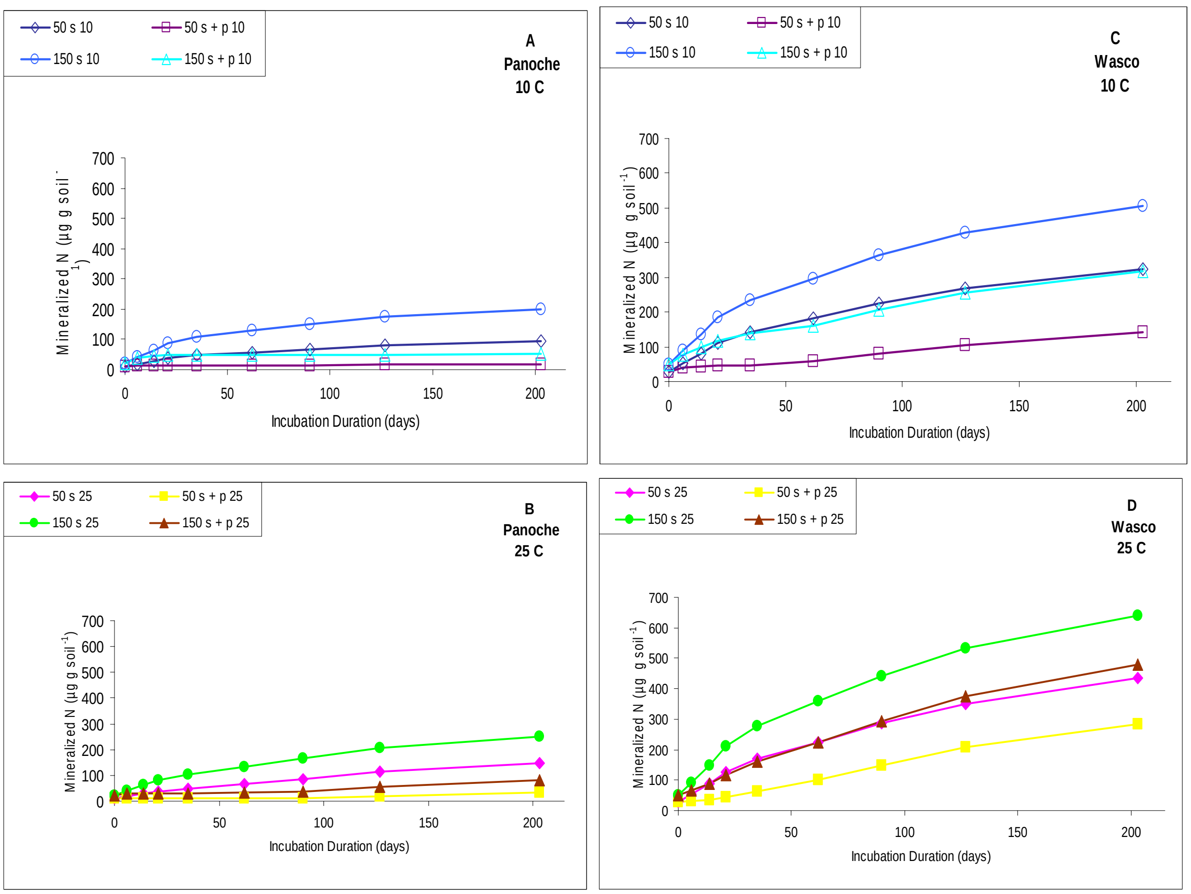
Figure 1. N mineralization from added cotton residues to a Panoche and Wasco soil. Incubated for 203 days at 10 and 25° C.



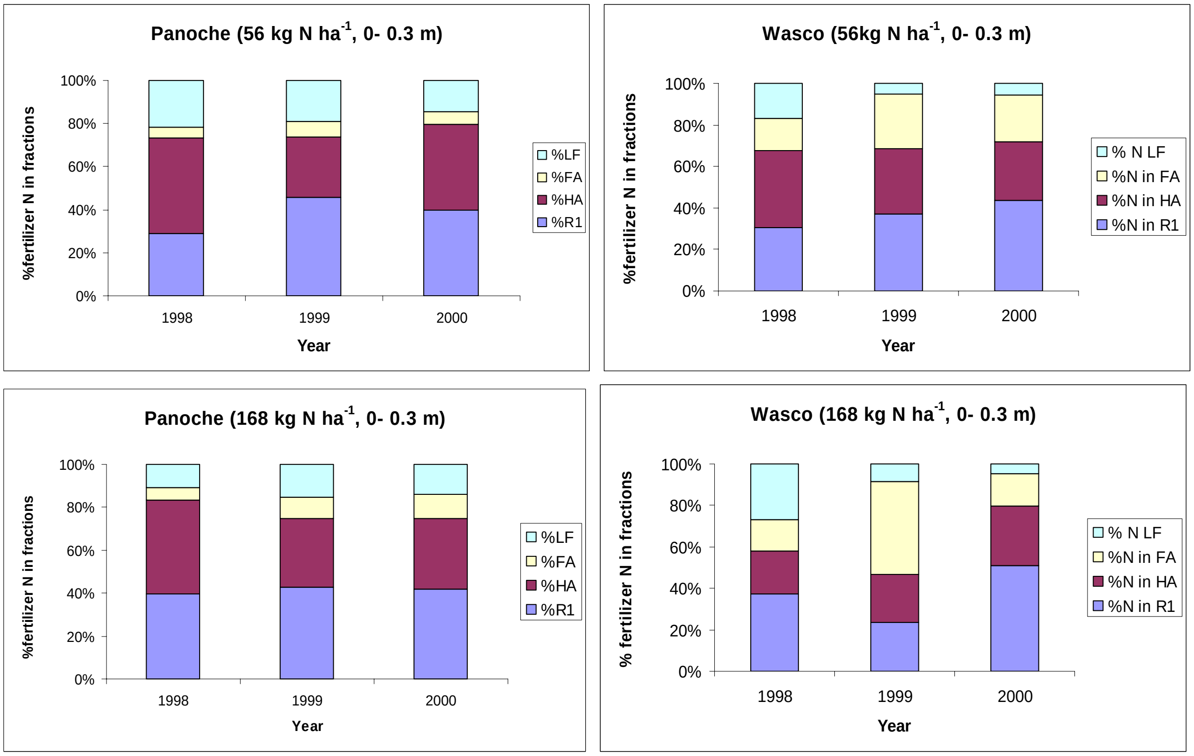
Treatments: 50 s 10 or 25: N treatment 58 kg ha^{-1}, soil only, incubated at 10° or 25° C.

150 s 10 or 25: N treatment 167 kg ha^{-1}, soil only, incubated at 10° or 25° C.

50 s+p 10 or 25: N treatment 58 kg ha^{-1}, soil plus plant residue, incubated at 10° or 25° C.

150 s+p 10 or 25: N treatment 167 kg ha^{-1}, soil plus plant, incubated at 10° or 25° C.

Figure 2. Percent of labeled fertilizer ^{15}N found in surface (0 – 0.3 m) soil organic matter fractions: light fraction (LF), fulvic acid (FA), humic acid (HA) and humins or residue (R1) for a Panoche clay loam and a Wasco sandy loam. N treatments of 56 and 168 kg ha^{-1}.



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2004 Poster Abstracts

Session Chair:

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CA Dept. of Pesticide Regulations

Ammonia Emissions from Site-Specific Variable Rate Nitrogen Applications in Cotton

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Precision agriculture is the term applied to the use of GPS for location and guidance of farm equipment in the field combined with GIS techniques to vary the application of seed, fertilizer, soil amendments, and pesticides in a site-specific manner. These precision agriculture practices allow the grower to match the yield potential of the soil in areas of the field as small as 10 square meters by adjusting the amount of product applied. The primary advantage is economic, as areas of the field with lower yield potential will only have the seed and fertilizer applied that are needed for those soil conditions. The advantage in regard to air quality is the reduction of the excessive amounts of nitrogen fertilizers being applied that may result in higher ammonia emissions. A nitrogen fertilizer trial in the southern part of the San Joaquin Valley was used to compare variable rate nitrogen application practices with conventional practices. Ammonia sampling was conducted before, during, and after the application, in an attempt to detect differences in ammonia emissions from the different nitrogen rates. The method utilized was active chemical filter packs or denuders at various elevations up to 10 meters. The test was conducted in 2003 and 2004. Levels of ammonia monitored seemed to track with applied amounts of anhydrous ammonia fertilizer. After three or four days ammonia monitored in the plots were close to background levels.

Salt Accumulation and Poor Irrigation Uniformity Lead to Production Problem in Greenhouse Chrysanthemum

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Economic pressures have been pressing several chrysanthemum growers, in Santa Clara County, to curtail their commercial operation and look for other economic ventures or completely cease operating business.

In addition, long-term practices of continuous fixed fertilization regimes and increasingly non-uniform irrigation systems have forced many of these growers to look for help to re-assess their operations status. Actual fertilization practices and schedules varied widely in this group, resulting in a wide range of severe under and/or over fertilization of the crop. Each grower's traditional fertilization and irrigation practices have caused significant soil chemical imbalances leading to increasing soil alkalinity or acidity, excessive accumulation of soil chloride (Cl), possible crop toxicity due to Cl, deficient or excessive soil nitrate levels, and or accumulation of exchangeable and soluble soil sodium (Na).
The main objectives of this work are to:

- Identify the source of quality problem facing growers
- Delineate different factors contributing to t flower quality problems
- Provide suggestions to overcome the operational and cultural limitations

Soil, water, and plant analyses revealed a long-term trend of soluble salt accumulation especially sodium (Na) and chloride (Cl). In addition, this accumulation seems to have been aggravated in most cases by less than optimal irrigation system design and/or operation resulting in poor distribution uniformity.

Well water analyses showed levels of Cl as high as 170 ppm (4.8 meq/L). Where no problems were reported where Cl levels were in the low 30's. Sodium concentrations in water were between 19 (0.8 meq/L) to 62 ppm (2.7 meq/L). Problematic production units had values of over 30 ppm (1.3 meq/L) of Na.

Poor well water quality (specifically high chloride) appears to play a prominent role in the production problems. Irrigation waters containing more than 2.5 meq/L Cl are not recommended for use in greenhouse production. Salts restrict root growth and limit their exploration for soil water and nutrients resulting in pale and stunted plants. Well water of most operations surveyed was below the critical level. However, in operations reflecting marginal economic return, well water tested above 4.9 meq/L. These high levels apparently result in serious plant injury especially in susceptible varieties. Common symptoms on foliage are leaf marginal burns and scorches.

Soil data paralleled water quality data. Soil pH varied low levels of 4 to the high values of 7.7 and 8. Optimum pH range for chrysanthemum is 5.5-7.0. Most operations had high values of Na, above the 125-ppm (3.5 meq/L) critical level. Sodium, not an essential macronutrient, is a component of soil salinity. Increases in soil sodium may also reduce water infiltration-percolation, thus reducing irrigation efficiency. When accumulated to high levels in plants, sodium becomes toxic. High levels of Na were detected in all or in parts of the soils studied. Depending on the crop’s growth cycle, variety, and irrigation efficiency, soil Na levels ranged from 3.0 meq/L to a very high 13 meq/L, while the average Na level was 8 meq/L.

Soil Cl was also elevated at levels 2- to 3-fold the threshold level of 3.5 meq/L. Chloride levels in the surveyed soils ranged from low (0.74 meq/l) to very high (14.0 meq/l) level. In three out of five surveyed operations, Cl levels exceeded the estimated threshold (3.5meq/L). In these houses Cl values ranged from 3.7 to 14 meq/L. Areas of poor production had levels of Na that ranged from 190 to 290 ppm, and Cl concentrations ranging from 4.8 to 14 meq/L.

Nitrate levels in the soil were highly variable between operations. Nitrate-N varied for very low (less than 10 ppm) to very high 380 ppm. Where problems related to Cl and Na were reported, NO_3-N levels were also in the excessive range of 90 to 380 ppm NO_3-N.

There is very little information in the literature on Cl effects on chrysanthemum plants. This is complicated by the observations that different varieties have different tolerance levels to Cl. Plants tissue analysis showed that typical leaf concentrations of more than 10,000 ppm of Cl did not have any apparent harmful effect. Some varieties, however, showed no tissue necrosis at levels as high as 24,000 ppm. Yet, others displayed severe foliar necrosis at 17000 ppm Cl.

From the preliminary analyses in 2003 and 2004, we are beginning to delineate a Cl range and its correlative effect on plant visual symptomology. Plant Cl content was apparently too high in three operations (at 17,000 ppm or above). For some varieties these levels tended to be very harmful and produced severe necrosis that was generalized to browning of lower leaves, tip-burn on upper leaves, and black spotting on stems. Plants displaying these symptoms tended to produce "softer" buds that later developed into smaller or low-grade flowers.

Visual observations indicated that symptoms of salt damage were more severe in certain areas of houses, especially those furthest from the irrigation head. Test results for micro-sprinkler irrigation systems confirmed that water distribution uniformity (DU) was very low in most operations. In several operations, DU was as low as 50 to 60% on lateral runs of 100 ft. In extreme cases DU was about 25%. Generally, uniformity problems can be traced to flaws in system design. The primary problem is due to under sizing of piping material. Therefore we believe that where water application was low, salt accumulation was excessive and thus the combined stress resulted in plants of marginal vigor and low quality flowers. Irrigation practices that did not include periodic leaching aggravated this condition. Areas where excessive water application was practiced tended to leach salts below root zone providing plants with relief from dissolved salts accumulated during irrigation runs. In addition to salinity impacts on root mass development, frequently imposed soil drying cycles to manage plant height often resulted in limited root systems.

Less than ideal fertilizer application and irrigation management combined with poor quality water have created adverse conditions for sustainable chrysanthemum production. In addition, Na and Cl accumulation, coupled with the use of low tolerance varieties led to serious reduction in flower production and quality. Generally, lack of irrigation uniformity has aggravated the negative effects of Na and Cl in areas of low water application.

To remedy these factors, we have presented the recommendations listed bellow to growers and encouraged them to adopt those that fit their specific conditions.

- Increase irrigation uniformity by increasing mainline pipe size.
- Adjust and vary irrigation frequency to plant growth stages not to set interval schedules
- Leach harmful salts away at frequencies individualized for each operation or sets of houses
- Avoid using chloride-containing fertilizers
- Monitor soil pH, particularly following lime or elemental sulfur applications

Use of Digital Electromagnetic Sensor For Soil Moisture Determination

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The principles behind the use of electromagnetic waves in moisture sensing technology are based on propagation of the waves through a media described by its magnetic and electrical properties. Water, which has a uniquely high permittivity, can be measured by its impact on the propagation velocity of electromagnetic waves through the medium containing water. The recognized leading technology for measuring soil moisture with electromagnetic probes is based on measuring the travel time of an electromagnetic wave over a given probe length commonly referred to as Time Domain Reflectometry (TDR) (Topp, 1993). More recently, a Time Domain Transmissometer (TDT), where the electromagnetic waves propagated from a transmitter directly to a receiver at the distal end of the transmission line, is being used (Blonquist et al, 2004; Adhikari and Goorahoo, 2004).

The goal of this study was to test the ability of a TDT sensor to provide reliable and repeatable results during multiple wetting cycles for various soil types, soil temperatures, and water salinity levels. In this phase of the project, we tested the response of a commercially available electromagnetic sensor to variation in soil moisture and solution electrical conductivity (EC) in a coarse, medium and fine textured soil at three temperature regimes.

Sensors were set up in rectangular boxes filled with coarse, fine and medium textured soils of known bulk densities. Soil was wetted up to saturation from the bottom of the box to limit air entrapment; allowed to drain to field capacity; and weighed periodically to determine the gravimetric and volumetric water contents. Tests were conducted at average temperatures of approximately 20^{o}C, 25^{o}C and 30^{o}C starting with the application water of deionized water and subsequent dosages of salt solutions of 1.5 dS/m. Calculated volumetric soil moisture contents were compared with values obtained from the computer readouts.

For the tests conducted at the 20, 25 and 30 °C temperatures with the application of increasing salt solutions on coarse, fine and medium textured soils, there were excellent linear correlations (r^2 ranging from 0.98 to 1.00) for medium and coarse textured soils between the volumetric water contents measured with the electromagnetic digital sensor and the calculated values (see Table 1 and Figure 1). However for fine textured soil the best correlation was found to be $r^2 = 0.675$ with a third degree polynomial fit. Additional tests are being conducted to further investigate the behavior of the TDT in fine textured soils.

The overall goal of our on-going research study is to contribute to efforts aimed at identifying and achieving exceptional water use efficiency in agricultural and landscape irrigation. In particular, the research will focus on soil moisture monitoring sensors. Secondly, we intend to verify the calibration accuracy of commercially available soil moisture sensors. Soil moisture sensors are an important component of some sensor-based irrigation system controllers. These results can then be utilized by the water purveyors as the basis for incentives and rebates program. The information presented in this poster represent one set of a series of tests conducted in evaluating a standardized testing protocol for soil moisture sensors.

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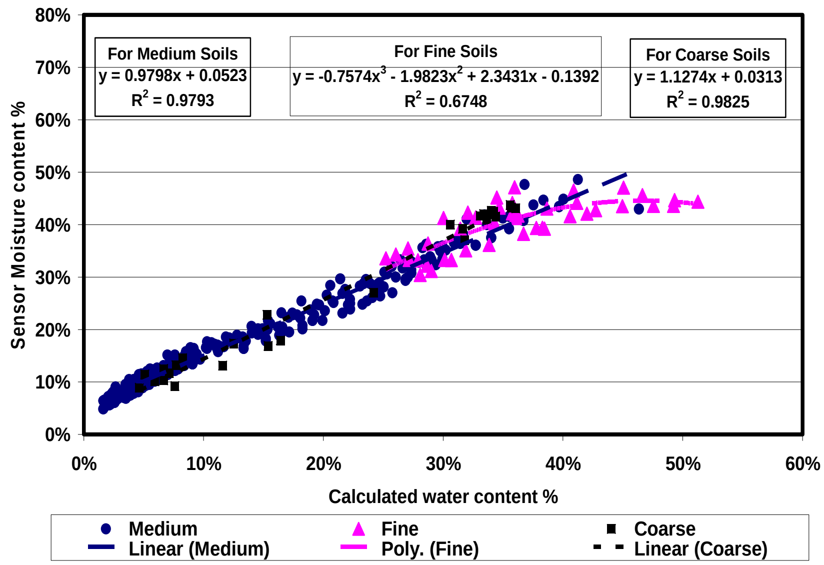

Figure 1: Plot of soil moisture sensor reading versus calculated water contents for sensors showing best fit regressions for data obtained for in coarse, fine and medium textured soils.

Table 1: Ranges of r^2 values obtained for the best fit regression equations describing the relationship between the sensor values and the calculated water contents for various tests.

Test no.	Subject of Test	Range of r^2 values
6.2.1	Calibration in a fine textured soil with 0dS/m water**	0.54 to 0.88
6.2.2	Calibration in a medium textured soil with 0dS/m water	0.99
6.2.3	Calibration in a coarse textured soil with 0dS/m water	0.99
6.3.1	Calibration at 20°C with 0dS/m water	0.97 to 0.98
6.3.2	Calibration at 30°C with 0dS/m water	0.95 to 0.99
6.3.3	Test for freezing susceptibility with 0dS/m water	*In progress*
6.4.1	Calibration when wetted with water with a conductivity of 1.0 dS/m on a medium textured soil	0.96 to 0.99
6.4.2	Calibration when wetted with water with a conductivity of 1.5 dS/m on a medium textured soil	0.99
6.4.3	3 Calibration when wetted with water with a conductivity of 3.0 dS/m on a medium textured soil	0.95 to 0.98
6.5.1	Calibration when wetted with water with a conductivity of 1.5 dS/m on a fine textured soil	In progress
6.5.2	Calibration when wetted with water with a conductivity of 1.5 dS/m on a coarse textured soil	In progress

An Interactive Web-Based Soil Survey Product for California

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Digital soil survey products developed by the USDA-NRCS National Cooperative Soil Survey Program (NCSS) constitute one of the largest geographic data sets in the world. The NCSS produces soil survey products at various scales providing soil resource conservation and management information at national, state, and county levels. Spatial- and attribute-data are stored in comprehensive data structures, making spatial analysis far more advanced and flexible compared to traditional soil surveys. However, high costs and complexity of commercial GIS software limits the average person's ability to access digital soil survey information. Although paper surveys exist for most parts of the State, many of these copies are out of print and are not easily accessible to the public.

With the previously mentioned advantages and disadvantages of the digital soil survey in mind, a project was devised that would make this material more accessible to the public. Open source software tools such as Mapserver, GDAL, MySQL, Apache, and PHP were used to create an interactive soils map of California using the State Soil Geographic Database (STATSGO, 1:250,000 scale) and Soil Survey Geographic Database (SSURGO 1:24,000 scale). Publicly available contextual geographic data such as 7.5 minute quadrangle borders, aerial photography, LANDSAT, urban areas, highways, and hydrography were incorporated into the system so that users can easily locate their position on the map. A dynamic legend and context map were designed to aid users in map interpretation. Soil map units can be queried with a mouse click, taking the user to a hierarchal summary of map units and soil components. At the map unit level, selected attribute data are summarized in tabular format. At the component level, selected attribute data is presented in tables and figures along with a diagram of a representative soil profile. Many concepts such as soil series, taxonomic information, or jargon specific to soil survey are linked to NRCS pages that contain detailed descriptions of terms.

The integrated linkage to outside information makes the online soil survey a useful tool for general soils education as well. A modular, object-oriented programming design makes it very simple to adapt the system to suggestions from outside sources. Furthermore, the modular design allows for simple integration of other spatial data sources, such as groundwater level maps or climatic data. Future work is planned that will facilitate the creation of dynamic thematic maps based on soil survey information.

Use of Elephant Grass as a Bio-Filter

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Excess nutrients from irrigation of crops with recycled wastewaters from food processing and dairy operations can be a major source of groundwater pollution. Hence, a major component of any Best Management Practice (BMP) should be the inclusion of either an agronomic crop or perennial forage capable of utilizing the wastewater nutrients. "Promor A" perennial forage grass (*Pennisetum Sp*.), commonly called Elephant grass, was introduced into California in 1994, and has been tested in at least five locations in the State. The Elephant grass is a luxury feeder of nitrogen and phosphorus and has the potential to absorb significant amounts of excess nutrients from dairy effluent and processing wastewater used for irrigation. Preliminary tests at California State University- Fresno have indicated that the grass can absorb up to 2000 pounds per acre of nitrates in a 60 day cutting cycle. This species can also absorb up to 1500 pounds per acre of phosphorus during the growing season.

In California, which is now the number one dairy producing State in the U.S. (CDFA 1999 & 2003), dairy manure is commonly handled as an effluent stream of liquid or slurry by means of a hydraulic flushing - lagoon storage - irrigation system. Major problems associated with the manure management are high solids and nutrient contents of the effluent stream. High solids content causes fast sludge buildup in storage lagoons, thus reducing the available storage volume, and also causes high solids loading to the soil when the wastewater is irrigated, hindering the crop seed germination and growth. High nutrient contents tend to cause overloading of land with nutrients, especially nitrogen and phosphates, causing contamination of surface and ground water resources.

The objective of this study was to conduct experimental studies to evaluate the benefits of planting Elephant grass in fields irrigated with dairy effluent water. In addition to the quantifying the yield and quality of the grass, we investigated the potential of the grass to act as a bio-filter for nitrate and phosphate. A final objective was to examine the water use efficiency (WUE) of the grass.

In the 1st Study, three acres of Elephant grass was planted at CSU Fresno and irrigated with well water for germination. Once germination was achieved it was irrigated exclusively irrigated with dairy pond water every 8-10 days for 6 months. The crop was harvested three times during this study. Dry matter (DM) yields averaged 23 T/ha which was about 17% of the total weight. The average of N and P content in the forage for the three harvests are given in Table 1.

Table 1: *N & P absorption in 1st study.*

Nutrient	% content in forage	Total absorption (kg/ha)
N	2.0	460
P	0.7	161

Additionally, it was observed that Total N accumulation in the forage was seven times greater in the stalk than the young leaves. Furthermore, the nutritional value of the forage demonstrated a high palatability and quality when fed to cattle.

In the 2nd study conducted at CSU Fresno on a sandy loam soil, N & P filtering characteristics of the forage was evaluated along with water consumption. Four drip irrigation treatments were set up at 40, 80, 120 and 160 % of daily measured reference evapotranspiration (ETo), and fertilized with UAN and P_2O_5. Results from this 2nd study are summarized in Tables 2, 3 and 4.

Table 2: *N & P absorption*

Year	N (kg/ha)	P (kg/ha)
2001-2002	542	185
2003	341	183
Total	883	368

Table 3: *Dry matter production.*

	T 1 – 40%	T2 – 80%	T3 - 120%	T4 -160%
DM (kg/ha)	52,586	74,774	76,839	78,142

Table 4*: Water Use Efficiency*

	T 1 – 40%	T2 – 80%	T3 - 120%	T4 -160%
Tons hay/ inch water	**0.87**	**0.77**	**0.61**	**0.55**

From the studies conducted to date, it can be concluded Elephant grass has significant potential for absorbing excess N and P in soils and hence can be a useful crop in bio-filtration phyto-remediation systems utilizing irrigation with recycled wastewaters. Furthermore, it was found to be a very cost-effective grass in lactating and fattening ratios. Water use efficiency was also demonstrated well at 80% ETo level being the most optimum.

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Using Constructed Wetlands To Remove Water Quality Contaminants In Agricultural Return Flows

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The Central Valley contains over 7 million acres of irrigated land representing over 25,000 dischargers. During the irrigation season, up to 50% of the flow in the San Joaquin River (SJR) can originate from irrigation return flows. Return flows contribute several water quality contaminants, including pesticides, nutrients, salt, selenium, boron, DOC, BOD (biological oxygen demand) and sediment. There is a critical need to identify and evaluate best management practices that improve water quality from irrigation return flows. Constructed flow-through wetlands (CWs) have great potential to mitigate several non-point source pollutants. However, no rigorous studies have scientifically evaluated the efficacy of CWs with respect to the complex suite of contaminants present in tailwaters. We are investigating the ability of CWs to improve water quality of irrigation return flows with respect to an entire suite of contaminants recognized by the 303d list and State basin plan. This research is being conducted in collaboration with the USDA-NRCS, US Bureau of Reclamation and participating land owners to monitor input and output waters of CWs that receive agricultural return flows from over 5,000 acres of farmland in western Stanislaus County.

This monitoring and research project is currently measuring input and output water volumes and contaminant loads at two CWs that receive irrigation return flows ultimately destined for the SJR. Our main objective is to evaluate the capacity of constructed wetlands to enhance water quality in agricultural return flows through their ability to filter contaminants such as sediment, nutrients, salts, BOD and organic carbon in irrigation return flows. The sites were selected to compare differences in wetland design (age, size, configuration & volume), emergent vegetation and hydrologic regime (e.g., quality and quantity of input/output water and hydrologic residence time). The CWs are located along the SJR between the confluences of the Merced and Tuolumne Rivers west of Patterson and Crows Landing and are representative of multiple projects funded by the Wetland Reserve Program and Environmental Quality Incentives Program (EQIP).

This research is investigating several questions concerning flow-through wetlands being constructed in the San Joaquin Valley. How do CWs influence the fate of nutrients, pesticides and total/dissolved organic carbon exported from agroecosytems? Do CWs act as sources or sinks of BOD? How do hydrologic residence time and wetland vegetation characteristics affect contaminant retention? Does contaminant removal efficiency change as CWs age?

There are several mechanisms acting in constructed wetlands that remove contaminants including: 1) sedimentation and burial (P, pesticides, particulate organic carbon, pathogens), 2) microbial transformations to gaseous forms (denitrification, methanogenesis, dimethylselinide), 3) plant uptake of nutrients and salts, and 4) microbial degradation of pesticides. As a result of these processes, it is commonly considered that wetlands have a beneficial effect on water quality (Jordan et al., 2003; Zedler, 2003). Important factors controlling the water purification capacity of wetlands include rate of contaminant inflows, residence time of water in the wetland, availability of organic matter and other substrates for growth of microbes, and nutrient uptake demand by plants (Phipps and Crumpton, 1994; Woltemade, 2000). This research is conducting a rigorous monitoring project to assess the fate and transport of contaminants through an investigation of relationships between sediment, vegetation, water, submerged soils and groundwater.

Preliminary monitoring, in 2004, of a newly constructed CW (W-1) and 10-year-old CW (W-2) suggests that CWs are efficient at removing sediment, nitrogen and phosphorus from irrigation return flows. The data also illustrates that W-2, the older CW, is a more efficient contaminant removal system. Average N removal efficiency was 44% for W-2 compared to 15.5% in W-1 (Figs. 1a & 1b). A comparison of TN concentrations in input waters and TN removal efficiency indicates that the magnitude of N removal was greatest when input levels of N were high (data not shown).

Similar trends were observed for phosphorus removal. Average P removal efficiency for W-1 was 19% compared to 59% (71% if outlier is removed) for W-2 the 10-yr-old CW (Figs. 2a & 2b). Removal efficiency at W-1 fluctuated throughout the season, whereas P was consistently sequestered in W-2 after the first week probably due to uptake by biota and/or sedimentation of particulate matter. Both W-1 and W-2 were highly effective at removing suspended solids from input waters 84% and 97% respectively, although, sediment removal efficiency was consistently higher at W-2 (Figs 3a & 3b). Wetland size and vegetation density are greater in W-2, which may promote particle settling through reduced water velocity and increased hydraulic residence time (Braskerud, 2002).

While wetlands may be a major sink for suspended solids, nutrients and pesticides, they may also be a source of algal biomass, DOC and particulate organic matter (Tockner et al., 1999). These components contribute to BOD in wetland drainage waters and could add to the BOD load causing hypoxia in the lower SJR. The high hydraulic residence time coupled with warm water temperatures in the shallow wetlands could enhance algae production in wetlands. Similarly, removal of suspended solids by wetlands may result in less turbid conditions in the SJR that in turn could result in enhanced algal growth due to greater light availability. Therefore, processing of irrigation tailwaters in flow-through wetlands may conceivably enhance hypoxia through increased algal production both within wetlands (algae exported to river) and within the main stem of the river. Thus, flow-through wetlands could simply serve as an incubator, transforming nutrients to algal biomass, resulting in no beneficial effect on BOD loads and DO in the lower SJR.

Our preliminary data for Chlorophyll-a indicate that CWs may not serve as incubators for algal growth. Large fluctuations input and output concentration occurred at W-1 (Fig 4a). Chlorophyll-a concentrations tended to be higher at W-1 compared to W-2. Input concentrations at W-2 were relatively consistent throughout the season. In addition, initial output concentrations at W-2 were high, but decreased over time, possibly due to the establishment of a plant canopy which decreased light penetration needed for algal growth (Fig. 4b).

Dissolved organic carbon (DOC) in the SJR/Delta system is a water quality concern because of production of mutagenic and carcinogenic disinfection by-products (DBP) during water treatment. The contribution of DOC from constructed wetlands to the SJR is not known. We are currently evaluating these risks and identify wetland management practices to minimize these adverse effects. By monitoring wetlands of contrasting age we will be able to assess temporal changes in wetland function. In addition, we will assess the effects of wetland design and hydrologic regime to optimize management strategies for water quality improvement.

This project directly addresses the needs of several TMDL efforts and related water quality issues in the lower SJR. The wetlands will serve as demonstration sites to extend information regarding implementation, management and maintenance of CWs. Information gained from this monitoring program will allow us to identify factors that may improve the functionality of CWs as water purifiers. This information will also provide a basis to recommend a monitoring protocol that will allow farmers to meet the agricultural waivers monitoring requirements in a scientifically sound and cost-effective manner.

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Figures of preliminary data collected in 2004 Irrigation Season

new wetland (W-1)	10-yr-old wetland (W-2)

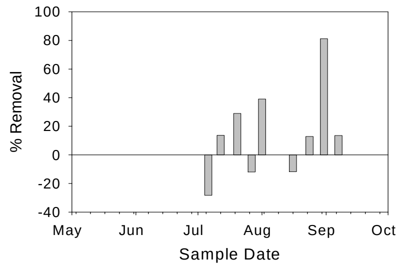

Figure 1a. Total Nitrogen removal efficiency for W-1.

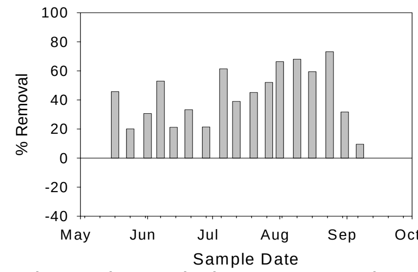

Figure 1b. Total Nitrogen removal efficiency for W-2.

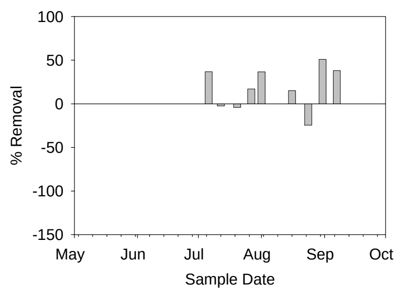

Figure 2a. Total Phosphorus removal efficiency for W-1.

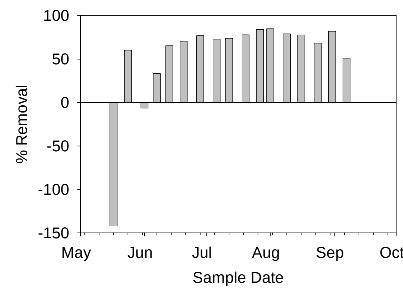

Figure 2b. Total Phosphorus removal efficiency for W-2.

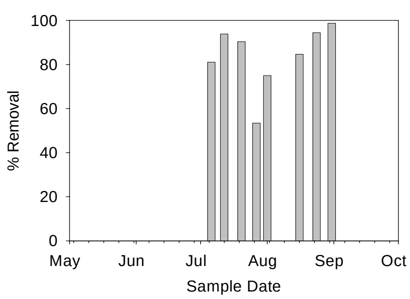

Figure 3a. Total Suspended solids removal efficiency for W-1.

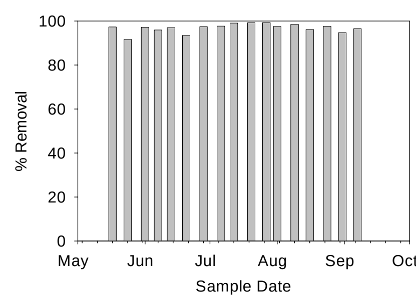

Figure 3b. Total suspended solids removal efficiency for W-2.

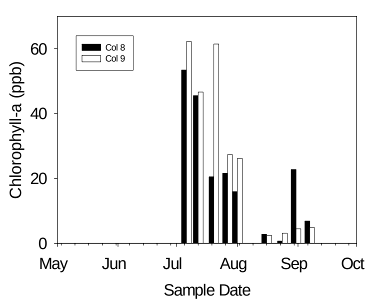

Figure 4a. Chlorophyll-a at W-1.

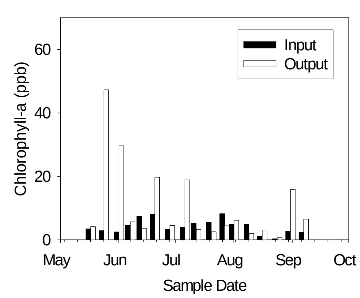

Figure 4b. Chlorophyll-a at W-2.

Estimating biological N fixation by winter cover crops on the Central Coast

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Nutrient budgets may help growers better estimate the relative input and output of nutrients in agricultural systems and thus manage the systems to minimize loss of excess nutrients and related time and expenses. Winter cover crops are an important component of nitrogen budgets for intensive vegetable production systems that are under organic fertility management. Accurate estimates of biological nitrogen fixation (BNF) allow the separation of the contribution of atmospheric N from the contribution of soil N to plant growth. Significant underestimates of fixation may overestimate loss of N from a system, while significant overestimates of fixation may lead to underestimates of N loss.

However, BNF varies with species, soil fertility and water availability, and fixation estimates can vary widely. For example, estimates for N fixation by bell beans (*Vicia faba*) vary from 58-88% of plant N derived from the atmosphere (%Ndfa) (Stivers and Shennan 1991, Amanuel et al. 2000, Mueller and Thorup-Kristensen 2001, Turpin et al. 2002). Farmers in California use a rough estimate of 12.3 – 41.2 kg N/ha for winter legume cover crop input.

We are trying to narrow this estimate by developing regional estimates of winter BNF by two common cover crops, woollypod vetch, *Vicia dasycarpa*, and bell beans using two methods, the traditional difference method and the natural abundance method.

The commonly used difference method determines the N content of a legume and of a non-fixing "reference" plant grown under the same conditions, and then attributes the difference in N content to fixation:

$$\%Ndfa = 100\ (\text{legume}\ \%N - \text{reference plant}\ \%N) / \text{legume}\ \%N$$

The method relies on the assumption that legume and reference species access N from similar pools in the soil and assimilate it at similar rates. However, the choice of reference species can have a strong influence on the estimate of fixation. To determine %Ndfa by the difference method, we grew bell beans and vetch in 2003-04 with oats (*Avena sativa*) and mustard (*Brassica japonica*) as reference species. The choice of reference species had a large effect on the estimated %Ndfa for vetch (Fig. 1). In addition, because mustard and oats produced greater biomass than the legumes in most plots, the difference method often gave negative estimates of %Ndfa (Fig. 1).

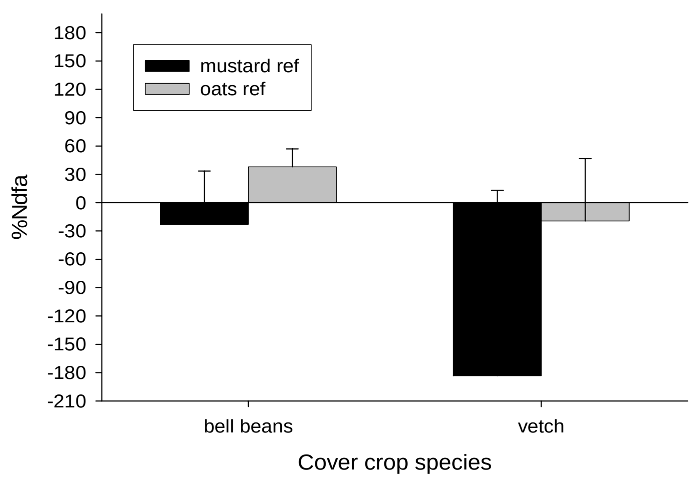

Figure 1. Mean %Ndfa as determined by the difference method, winter 2003-04.

An alternative may be the ^{15}N natural abundance method, which uses the difference between $\delta^{15}N$ of the soil and $\delta^{15}N$ of the atmosphere to determine %Ndfa. Here BNF is calculated as:

$$\textbf{\%N derived from the atm} = 100\,(\delta^{15}N_{ref} - \delta^{15}N_{leg})/(\delta^{15}N_{ref} - B)$$

where $\delta^{15}N_{ref}$ is the signature of a non-legume cover crop in field plots, $\delta^{15}N_{leg}$ is the signature of a legume cover crop in field plots, and B is the $\delta^{15}N$ signature of a legume when all N is derived from fixation (Hardarson and Atkins 2003). The reference plant here is meant to integrate the $\delta^{15}N$ signature of the soil N available for plant growth during the study period (Boddey et al. 2000). This is less problematic than the use of a reference plant in the difference method because it represents the *signature* of the N pools available for plant growth instead of the *total* N available. However, it still assumes that the pools of N accessed by the legume and reference plants are the same (Schneider 2003).

The natural abundance method works best if: 1) there are only two pools of N available to the legumes (plant-available forms in the soil and atmospheric N_2); 2) the two pools have significantly different $\delta^{15}N$ signatures; and 3) the variability of the signatures is low compared to the difference between them (Ellis et al. 2000). As a result, this method may have limitations for use in fields that have had frequent inputs derived from legumes. This problem may be greatest in fields where legumes are routinely used as cover crops and the entire biomass incorporated, such that the soil signature would become closer to the air signature over time. We saw evidence of this potential problem in 2002-03 and 2003-04.

In 2002-03, we began experiments to determine %Ndfa by the natural abundance method. To determine B in the natural abundance method equation, we grew bell beans and vetch separately in root boxes filled with sand and quartz gravel. We supplied the plants with an N-free modified Hoagland's solution. To determine $\delta^{15}N_{leg}$, we grew bell beans and vetch in root boxes filled with soil from the farm's orchard and in five field plots. To determine $\delta^{15}N_{ref}$, we grew oats and mustard separately in field plots adjacent to the bell beans and vetch.

There was no significant difference between $\delta^{15}N$ signatures of legumes grown in the sand-gravel mix and legumes grown in a field with a long (>10 year) history of winter legume cover cropping (results shown for vetch in Fig. 2; bell beans showed the same pattern). However, there was a significant difference between $\delta^{15}N$ signatures of legumes grown in the sand-gravel mix and legumes grown in root boxes with soil from the orchard (Fig. 2), which has no history of winter legume cover cropping. We suspected that a long history of incorporating legume cover crops in the field caused the soil $\delta^{15}N$ signature to be more similar to the signature of legumes fixing all of their own N than to the orchard soil, and that this was reflected in the signatures of the plants from those locations.

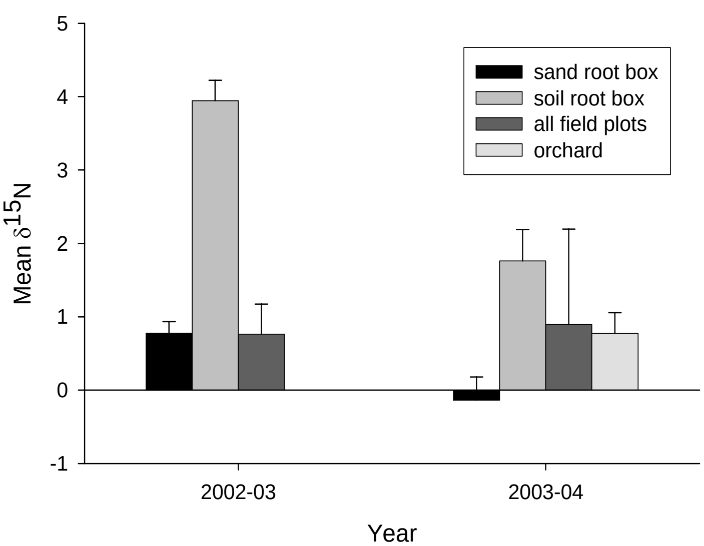

Figure 2. Mean $\delta^{15}N$ of vetch planted in three locations at the CASFS Farm in winter 2002-03 and in four locations in winter 2004-05.

We replanted the experiment in 2003-04, using larger plots (2.8 x 7.6 m) in five fields with a range of legume cover crop histories, from no previous legume cover crops to 20 years of winter legume cover cropping. The results in the second year were generally consistent with the first (Fig. 2) but opened more questions. For example, the $\delta^{15}N$ signature of vetch planted in root boxes filled with orchard soil was significantly different from the signature of vetch planted in the orchard itself. In addition, vetch from the five fields with a range of legume cover cropping histories did not show the expected pattern of plants in the fields with the longest history having the lowest $\delta^{15}N$ signatures (therefore closest in ^{15}N composition to the air) and plants in fields with no history having the highest signatures. Bell beans, however, showed a pattern more similar to the expected one.

When calculating %Ndfa by the natural abundance method, estimates were generally high but broadly ranging. For example, vetch in the field plots had a range of 42-95 %Ndfa when using oats as a reference. For bell beans, estimates were 87-103 % Ndfa when using oats as a reference. Such high values of fixation, especially those over 100%, are questionable, particularly in fields with high levels of available N in the soil during the cover crop growing season. However, choice of reference species had a much lower effect on %Ndfa estimates by the natural abundance method than by the difference method. At this point neither method seems to provide a reasonably small range of fixation estimates for use in budgets.

We are continuing to research the two methods of estimating N fixation. We have replanted the trials this winter, including phacelia (*Phacelia tanacetifolia*) and mustard (*Brassica juncea*, Pacific Gold cv.) as additional reference species. In addition, we have established fertility treatments within the field plots to determine if field fertility levels affect the plants' isotopic signatures and thus potentially interact with field cover crop history.

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Mapping K-fixing Soils in California: A New Application of Soil Survey Data

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More than forty years ago, University of California researchers proved that vermiculite, a K-fixing mineral, was in part responsible for K deficiencies in cotton observed in the San Joaquin Valley. In spite of much research conducted over the past 50 years to relate this problem to field symptoms and to develop diagnostic criteria, the location of K-fixing soils in the SJV has not been mapped. Based on an assumed relationship to clay content, Miller et al. (1997) suggested that 60% of the cotton-producing land in the SJV is vermiculitic; however our laboratory studies indicates that K-fixation occurs in the silt and fine-sand size fraction of the soil. With the digitization of soil surveys by the USDA-NRCS Cooperative Soil Survey, we asked whether it would be possible to model and map K fixation potential of soils based on soil properties that can be accessed in national soils databases together with other geologic considerations. We produced a map of potentially K-fixing soils covering four counties and seven Order 2 soil surveys in the San Joaquin Valley. We chose location (soils formed from Sierra Nevadan parent material) and particle size class as selection criteria. The particle size class is determined by the profile control section, generally 25 – 100 cm deep or the upper 50 cm of the argillic horizon.

This is somewhat deeper than both the depth of nutrient and water extraction by cotton and the UC-recommended depth (15 – 46 cm) of soil sampling for assessment of soil K status (Miller et al., 1997). It would be possible also to select soils according to particle size of individual horizons; however, the variability in those data would be much greater. More specific parent material information in the soil series and map unit descriptions would have been useful for our mapping exercise. Parent material is not used as a differentiating characteristic for soil series, and terminology in map unit descriptions that describes parent material is inconsistent.

Ag Water Use Efficiency and Irrigation Scheduling in the Southern San Joaquin Valley

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Agricultural water use efficiency (AgWUE) is generally perceived as being somewhere between 65 to 85% depending on the crop, irrigation system and cost of water; with regional averages often placed around 75%. The current CALFED policy driving water planning in California emphasizes water conservation over building new storage to supply growing urban demands; with AgWUE improvements seen as the largest potential "supply". The assumption is that there is still significant room for improvement. However, little documentation exists on a regional basis describing actual AgWUE over a large number of fields and grower receptiveness to "scientific irrigation scheduling".

Starting Winter 2001 an irrigation scheduling demonstration program was initiated in Kern County to instrument grower's fields with soil moisture tension monitoring equipment (electrical resistance blocks, Watermark®) and loggers with a visual display (MK Hanson AM400®). A neutron backscatter moisture meter (CPN Hydroprobe 503DR) was also used for volumetric soil moisture determination. Growers were faxed one page weekly scheduling recommendations with weather-based estimates of ET, real-time soil moisture and applied water history. Additional fields totaling 7,400 acres were added to this program in 2002 as part of a CalFed AgWUE project; **Quantification of Benefits Attributable to Irrigation Scheduling as an On-Farm Water Management Tool**. More grower fields were set up in 2003 and 2004.

A total of 110 fields covering 9,000 acres belonging to 24 different growers were instrumented over this time period in 12 different crops, 11 soil textures and 9 different irrigation system types. The frequency of grower use of field loggers and faxed irrigation schedules ranged from almost nil to very high. Many fields using microirrigation were near optimal or deficit irrigated before entering the program; requiring an increase in applied water. AgWUE using weather-based ET averaged 96% and 97% using soil moisture depletion.

In the San Joaquin Valley there is less water to be "saved" by improving AgWUE than assumed. As expected, furrow systems in field crops were the most responsive to increased monitoring. Existing micro systems are mostly at maximum efficiency. Growers are receptive to new technology/scheduling but only with regular personal consultation and financial incentives will they adopt these techniques.

Soil Water Retention Characteristics for Soils Irrigated with Saline-Sodic Drainage Water

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Current research conducted in agricultural areas in California, such as in the Imperial and San Joaquin Valley's, are aimed at reducing the volume of irrigation water applied and subsurface drainage by encouraging crop utilization of shallow groundwater, while still maximizing yields in saline soils. Soil salinity, shallow saline groundwater, and drainage water disposal all pose major challenges to agriculture on the west side of the San Joaquin Valley (SJV) (San Joaquin Valley Drainage Implementation Program, 1990). These soil constraints reduce yields and profitability, and they limit crop choices. Farmers are looking at management practices that will allow the production of agronomic crops utilizing low quality irrigation waters. The increased demands for fresh water is growing steadily in arid regions and it is likely that irrigation with saline and saline-sodic water sources will be used to a greater extent. Saline-sodic irrigation water can degrade soil structure, and thereby reduce the rate at which water infiltrates the soil, otherwise known as the soil water retention (SWR) curve.

Current infiltration models lack variables that account for different management practices. A study to provide expected soil water retention curve rates for soils affected by saline-sodic irrigation water management practices would prove valuable to on-going and future research. Refining the management of soils that are being irrigated with saline-sodic water is essential for the sustainability of agriculture on the Westside San Joaquin Valley.

The major objective of this study was to determine the SWR curve characteristics of soils irrigated with recycled saline-sodic drainage water for the eventual use of these parameters in irrigation management models. In addition, the correlation between the parameters of the SWR curves and the soil salinity were also investigated.

The soil was selected from the west side San Joaquin Valley, California at Red Rock Ranch (RRR) in Five Points (Figure 1). Soil was taken from a fresh-water irrigated area (Stage 1) and from each subsequent area that has been irrigated with recycled drainage water for seven years (Stages 2- 4). Irrigation water salinity in Stage 1 is generally less than 1 dS/m and in Stage 4 it averages about 13 dS/m. Hand augers were utilized to collect core samples to a 120 cm depth at 30-cm increments. Texture, pH, EC, and SAR analysis were conducted on samples from all locations and depths.

Saturated hydraulic conductivity (Ks), water retention, gravimetric/ volumetric water content, and bulk density were also determined for these samples. Soil water retention (SWR) curves were obtained from data collected utilizing the pressure plate apparatus (van Genuchten, 1980). The non-linear least squares optimization program, RETC, available from the USDA Soil Salinity Laboratory in Riverside, CA (van Genuchten et al., 1991) was used to curve fit the data. SWR parameters were compared with soil salinity at the varying depths for the Stage 4 to examine the degree of linear correlations.

The textural analysis and soil classification for soils collected from each stage are shown in Table 1. Based on the USDA soil classification system the soils from the four stages were all clay loams, which is similar to analyses presented by Nielsen et al. (1964) for soils collected at the nearby Westside field station.

Soil salinity (ECe) listed in Table 2 was less than 2.4 dS/m in Stage 1 to greater than 50 dS/m in Stage 4 and SAR was 8.6 and 85.4 for Stages 1 and 4, respectively. The natural process of salts accumulation in irrigated agriculture was evident in Stage 1 at the onset with such high EC and SAR values. Saturated flow rates (Ks) ranged from 1.02×10^{-3} to 7.58×10^{-7} cm s^{-1} from Stage 1 to Stage 4, respectively.

Soil water retention curve data fitted with the RETC program yielded an estimation of volumetric water content at saturation (θ_s) and empirical parameters α and n data for each sample and depth, which in turn predicted the K (ψ) and θ (ψ) values necessary for the creation of irrigation modeling tools for improved management in the Red Rock Ranch IFDM demonstration project. Generally, the θ_s values predicted for Stages 1 to 3 with the curve fitting procedure (Table3) were lower than the volumetric water contents estimated from the saturation percentage analyses. In the case of stage 4, the mean θ_s value of 64.7% falls close to the 66% to 73% range of the saturated percentages. The CV values for θ_s ranged from 20% from stage 1 to 46% for stage 3, which implied that this property was considerably more variable than the saturated water content typically reported in the literature (CV for θ_s = 15%) (Warrick, 1998).

Generally, the mean values of the air entry index α decreased dramatically in moving from stage 1 to stage 4 (Table3). The empirical curve fitting parameter α is the inverse of the air-entry (or bubbling pressure) of the soil (van Genuchten and Nielsen, 1985). This means that the higher the value of α, then the lower is the pressure required to drain water from the soil pores. Or, stated another way, a lower α value would mean that a plant would have to exert higher tension or pull to extract water from the soil pores.

The pore size distribution factor (n) was greatest in stage 4 at 1.73 and smallest in stage 2 at 1.12. While stages 1, 2, and 3 shared similar n values, soils from stage 4 demonstrated a significant increase over those from the other three stages. The dimensionless parameter, n, is related to the slope of the θ (ψ) curve and is inversely related to the width of the soil pore size distribution (Russo, 1988).

In an attempt to find and establish a correlation between the reduced hydraulic conductivity and soil moisture data with the chemical characteristics of the soil, an analysis of the θ_s, α, and n values for stage 4 by depth were compared with the stage 4 EC and SAR values (Table 4.). The best correlations found were those between θ_s and n, which are both hydraulic properties, and between EC and SAR, which are both chemical properties. No significant correlation was found to link the observed soil hydraulic characteristics with the chemical characteristics of the soils.

SWR curves vary with time, soil type, texture, and the degree to which the soil has salinized and/or become sodic. Researchers have not clearly defined the degree to which SWR curves may be reduced in saline-sodic soils in the SJV. It is known, however, that variability in soil salinity and SWR curve rates in a field will strongly influence the performance and management of surface irrigation systems. For fields irrigated with saline-sodic irrigation water, there exists small scale and localized variability in SWR and other hydraulic properties. Characterization of these properties is essential for better understanding of flow and solute transport in the vadose zone.

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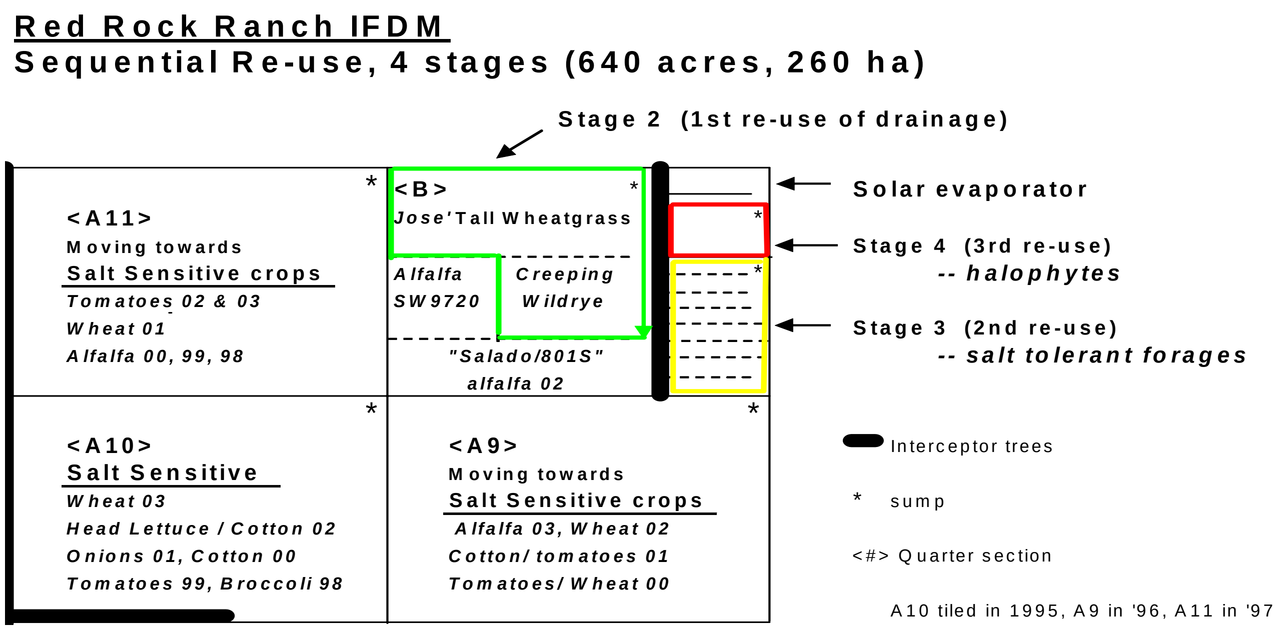

Fig. 1. Map of Red Rock Ranch on the Westside of the San Joaquin Valley in Five Points, four stages of the re-use scheme. Field A9 (Stage 1) receives fresh water irrigation. Tile drains in the northeast corner of each field collect the drainage water for its use in each subsequent stage of the sequential reuse system.

Table 1. Soil Textures for Stages 1 to 4 at Red Rock Ranch.

Stage	% Sand	% Silt	% Clay	Texture
1	38.6	25.7	35.7	Clay loam
2	41.0	20.7	38.3	Clay loam
3	34.0	31.9	34.1	Clay loam
4	43.1	29.4	34.6	Clay loam

Table 2. Mean Soil Chemical Properties for RRR.

Stage	pH	EC	SAR
1	7.45	6.1	19.52
2	7.44	13.23	23.82
3	7.46	15.25	28.74
4	7.79	27.71	58.94

Table 3. Mean values for Soil Hydraulic Parameters obtained by Curve Fitting the SWR Data for RRR.

Stage	θs	α	*n*
1	0.477	0.045	1.23
2	0.523	0.025	1.121
3	0.446	0.012	1.275
4	0.647	0.001	1.729

Table 4. Correlation Values for Hydraulic Parameters for RRR.

	θs	α	*n*	EC	SAR
θs	1				
α	0.119	1			
n	0.302	0.001	1		
EC	0.035	-0.169	0.172	1	
SAR	-0.224	-0.160	0.053	0.668	1

Optimization of Manure Application Rates

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A linear optimization model has been developed to identify an optimal and sustainable application schedule expected to meet PAN needs while minimizing the potential for losses to groundwater. The model assumes that a farmer is able to identify potential application dates and that targets for supplying plant available N (PAN) are also available. Estimates of manure N, N inorganic-organic partitioning, and expected mineralization rate are also needed. The model also depends on soil temperature information to modify mineralization rates. It assumes that manure properties and soil temperatures are the most important factor affecting mineralization rates. In California most manured systems are irrigated during dry months when soil moisture would otherwise be likely to constrain mineralization. Freeze-thaw affects are not considered by the model. The system is assumed to be at steady-state in the sense that soil organic N derived from the organic fertilizer varies seasonally, but not from year-to-year.

N mineralization from applied organic fertilizers is often represented as a first-order process. Under field conditions, however, the decay rates vary with temperature. This normally requires a numerical solution, but use of temperature-adjusted time (TAT) allow the effects of temperature to be considered simultaneously (Crohn and Valenzuela-Solano 2003). The result is similar to growing-degree days, but is more consistent with principals of biochemistry. Fig. 1 compares mean daily soil temperatures at Modesto, CA to cumulative TAT. Temperature values were averaged from CIMIS data (California Irrigation Management Information System) representing the period from 1988-2004.

When organic fertilizers are applied in a consistent pattern a steady-state condition is eventually reached. Simulations reported by Chang et al. (2005) estimate that a newly manured field will approximate steady-state in the San Joaquin Valley or similar conditions will be reached within four to seven years, depending on the mineralization rate. Assumption of a steady-state condition allows for the construction of an optimization model for land application rates. The model minimizes N losses while guaranteeing the crop N demands. Because this model is linear, it can be solved for quickly and precisely using an optimization algorithm, such as Microsoft Excel's Solver, that includes a linear model (simplex method) option.

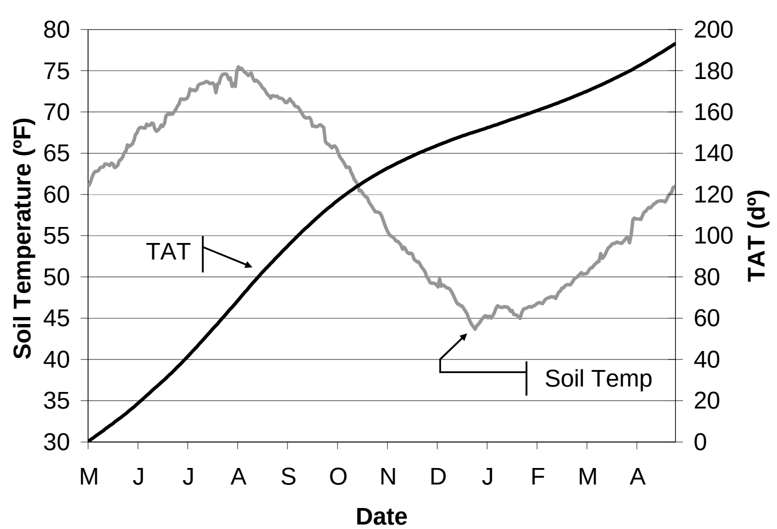

Fig. 1 Mean daily soil temperatures (15 cm) and cumulative TAT (T_r=25ºC, Q_{10}=2) for Modesto, CA.

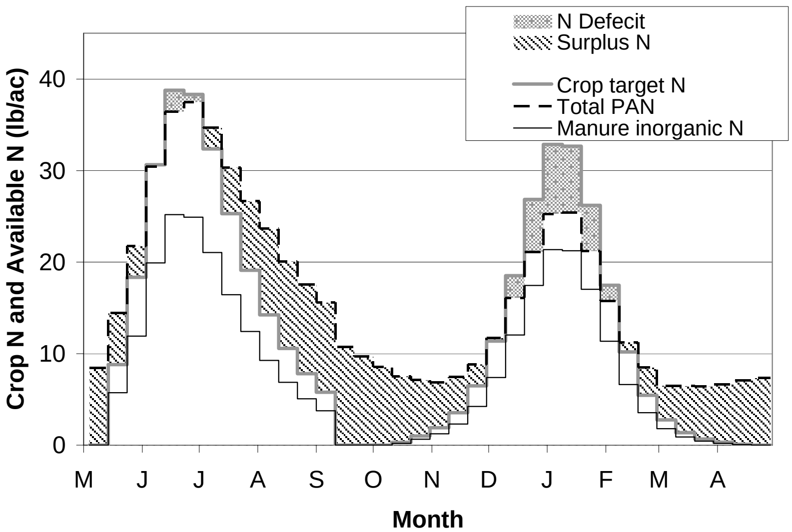

Fig. 2 Total crop N demand, manure inorganic N, and manure-derived PAN during 10-day planning periods. PAN is the manure inorganic N + mineralized N

The example considers dairy manure lagoon water from a hypothetical farming operation located in Stanislaus County, California. Two forage crops are grown in rotation; summer forage corn and winter triticale. Plans called for growing forage corn from May 14 through Sept. 11 and triticale from Oct. 16 through Apr. 14. Cumulative crop N demand was 250 lb/ac for corn and 200 lb/ac for triticale. The curves were fit to data supplied by a local University of California Cooperative Extension agronomist (Marsha Campbell Matthews, personal communication). For illustrative purposes, I first consider a rotation scheduled to receive applications throughout the year at 10-day intervals. The planning year begins May 1 and the 10-day application cycle initiates May 4.

Chang et al. (2005) used detailed simulation models to conclude that crops supplied with 20 to 40 percent more N than their annual uptake would present acceptable yields while avoiding excessive impacts on groundwater quality. Fig. 2 illustrates a nitrogen management plan resulting from applications of 30% above crop demand during 10-day management intervals. Each straight horizontal line segment represents the total value for planning period so that, for example, the total N to be supplied to the crop during the planning period from June 13 to June 23 is 38.8 lbs. Manure inorganic N is assumed to be 50% of total for this lagoon water example. Total PAN includes both inorganic N and mineralized organic N. Shaded areas represent periods of N surplus and N deficit with respect to crop N supply targets. This example applied 585 lb/ac/yr total manure N to supply a total crop demand of 450 lb/ac/yr. The total N surplus, or leachable N, for the year, is while the total crop deficit is 168 lb/ac/yr while the total deficit is 33 lb/ac/yr. Fig. 3 presents the

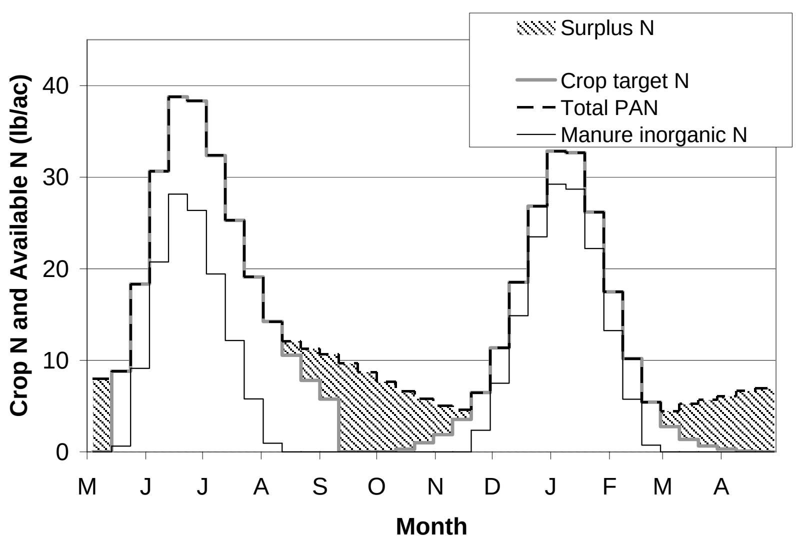

Fig. 3 Total crop N demand, manure inorganic N, and manure-derived PAN during 10-day planning periods. PAN is the manure inorganic N + mineralized N

corresponding optimized result, which requires the application of 545 lb/ac/yr. The optimized result has no crop deficit N while excess N is limited to 95 lb/ac/yr due to mineralization of organic N during periods of little or no crop uptake. Fig. 4 compares 30% above crop demand application rates to the optimized solution. Optimization decreases applications late in the summer growing season and increases rates during the winter when cool weather depresses organic N mineralization.

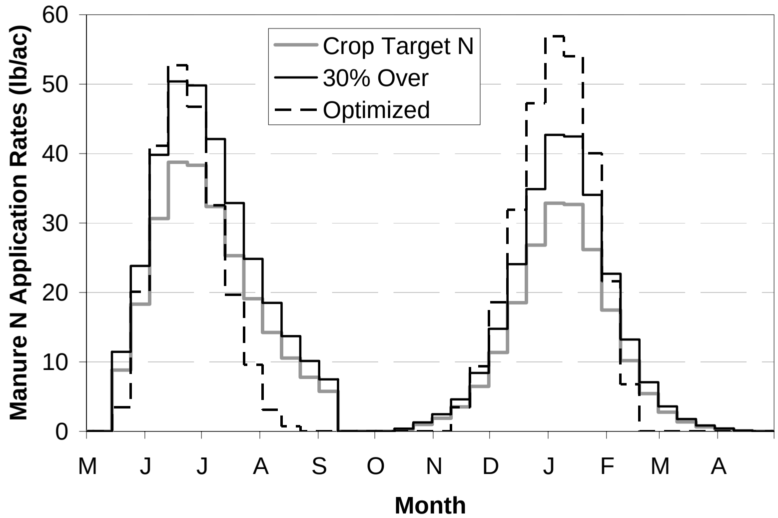

Fig. 4 Application rates

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Biomass Production & Nutritional Value of Forages Irrigated with Saline-sodic Drainage Water: field and greenhouse studies

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Introduction

Reuse of saline drainage water (DW) is a management option that has been proposed for the Westside San Joaquin Valley (SJV) in order to reduce both the area affected by shallow water tables and the volume of drainage effluent requiring disposal (San Joaquin Valley Drainage Implementation Program, 2000). Objectives of the approach are to manage salt and DW on the farm (IFDM), or regional scale, and at the same time to minimize environmental impacts such as salt loading into rivers and risks to wildlife from selenium or other trace elements present in the DW. Forage production is particularly appealing for DW re-use systems because of the very high degree of salt tolerance demonstrated by some of the forages tested (Grattan et al., 2004), and a growing local demand for forage material due to the rapid influx of dairies into the SJV in recent years. Cultivation of salt-tolerant forages would not only increase forage supplies, but it can play a key role in drainage water management (Qadir & Oster, 2004).

Forage selection for DW reuse systems should be based on their demonstrated ability to maintain productivity over the long term in soils irrigated with saline-sodic DW. Depending on the characteristics of the DW, these soils are likely to experience sodium-induced clay dispersion and have reduced infiltration and low permeability to water and oxygen (Grattan & Oster, 2002; Senatore et al., 2004). Several salt tolerant forages performed well under DW irrigation in a sand tank study at the USDA Salinity Laboratory in Riverside, CA (USSL) (Grattan et al., 2004). Some of the same forages have been evaluated for two years in large field plots at Red Rock Ranch (RRR) in Five Points, CA in soils that have received DW irrigation for four to five years and are now in very poor physical condition. Because of the large variation in soil salinity amongst the forage stands at RRR, we also conducted a greenhouse study to evaluate the more promising forages in a field soil: sand mix under uniform and controlled soil conditions.

The objectives of this research are to: 1) evaluate the suitability of these forages for long-term irrigation with saline-sodic DW, and 2) to assess their productivity, nutritional value, and safety for feeding to animals after multiple years of DW irrigation.

Materials and Methods

Field Study at RRR

Six forages were evaluated during fall 2002 to fall 2004 at RRR. The forages were tall wheatgrass (*Thinopyrum ponticum* var. '*Jose*', formally classified as *Agropyron elongatum* var. '*Jose*'), creeping wildrye (*Leymus triticoides* var. '*Rio*'), alfalfa (*Medicago sativum* var. *Salado*'), tall fescue (*Festuca arundinacea* var. '*Alta*'), alkali sacaton (*Sporobolus airoides* var.'*solado*'), and puccinellia (*Puccinellia ciliata*). All forages were DW-irrigated with the exception of the '*salado*' alfalfa which was fresh water irrigated, but growing in soil that had been previously irrigated with DW.

Productivity was measured using a rotational cutting system. The entire forage plot was initially cut to 15 cm (6 in.) and then cuts were taken in 1 m^2 sub-plots when the stand reached 30 cm (12 in.), 45 cm (18 in.), and its final height prior to heading, or flowering for alfalfa. Organic forage quality was measured as metabolizable energy (ME) using a rumen fluid gas test (Robinson & Getachew, 2002); and as crude protein (CP), neutral detergent fiber (NDF), and ash using standard laboratory procedures. Mineral analyses (Ca, Mg, P, S, Na, Cl, B, Se, and NO_3) were performed at the UC-DANR Analytical Lab, Davis, CA.

Greenhouse Study

Five salt-tolerant forages were tested in a greenhouse at CSU Fresno from January 2003 to December 2004. The forages were tall wheatgrass (*T. ponticum* var. '*Jose*'), creeping wildrye (*L. triticoides* var. '*Rio*'), alfalfa (*M. sativum* var. '*salado*'), paspalum (*Paspalum vaginatum* var. '*Sealsle 1*'), and bermudagrass (*Cynodon dactylum* var. '*Giant*'). The treatments consisted of three irrigation water qualities: non-saline (NS; 0.5 – 0.9 dS/m), low saline (LS; 8 – 10 dS/m), and high saline (HS; 18 – 20 dS/m) that were applied in a randomized complete block experimental design. Saline treatments began at half strength and were increased to full strength within 25 days. Tap water was used for the NS treatment and concentrated DW from RRR was diluted for the LS and HS treatments. Fertilizers were added to the irrigation waters to bring final concentrations to approximately 107 mg/L (ppm) K, 15.5 mg/L P, 31 mg/L Ca, and 20uM Fe. Nitrogen was only added to the NS treatment to balance its N level with that of the LS treatment (64 mg/L NO_3-N, entirely from the DW). The N level in the HS treatment was 115 mg/L NO_3-N.

The forages were germinated in a greenhouse soil mix (peat, perlite, and vermiculite) and then transplanted into pots 25 cm (10 in.) in diameter × 30 cm (12 in.) in depth. The pots were filled with a soil mixture consisting of 60 % clay soil and 40 % sand. The clay soil was collected from a fresh water-irrigated field at RRR, and was sieved using a 2.5 cm (1 in.) diameter screen. The grass forages were cut just prior to heading and alfalfa was cut at 10 % bloom. Dry matter accumulation was measured as the sum of all the cuts taken over the one year period. Relative yields were calculated as the ratio between the dry matter of LS or HS and the dry matter of the NS treatment. The same forage quality and mineral analyses were measured as in the field study.

Results and Discussion

Field study at RRR

Creeping wildrye (CWR) growing in less saline fields (ECe = 13.3 and 13.5 dS/m) produced from 10 to 13.8 MT DM / ha annually (Fig. 1). Tall wheatgrass (TWG) growing in much more saline fields (ECe = 20.3 and 17.5 dS/m ECe) had good biomass production (6 to 8 MT DM/ha). The very low yield (< 3 MT / ha) measured in one TWG field was due to insufficient irrigation. Puccinellia, alkali sacaton (AS), and tall fescue (TF) produced between 4 to 8 MT/ha/yr of DM.

Metabolizable energy (ME) of the DW-irrigated forages was 7 to 10 MJ/ kg DM, a range considered to be "medium quality" for cattle (Table 1.). MEs of less than 7 MJ/ kg DM are not acceptable for dairy cow feeding. Amongst the grass forages, tall wheatgrass and tall fescue had higher ME (desirable) and lower NDF (desirable) than the others. Ash content was 7 to 10.8% for all forages and was not increased by DW irrigation. Nitrate concentrations in all DW-irrigated forages were below 200 ppm NO_3-N, the safe range for animal feeding. However, due to the high nitrate in the DW (21– 44 mg/L NO_3-N), forage nitrate will continue to be monitored.

Selenium (Se) levels in the DW-irrigated forages at RRR were very high (1.9 to 8.4 ppm (mg/kg DM)), presumably due to the high concentrations of Se in the applied DW (0.8 to 1.2 mg/L) (Table 1.). Levels of most other minerals were either below or within the ranges set as maximum tolerable concentrations (MTCs) for animal feeds. The exception was sulfur which in tall fescue and alkali sacaton was above the MTC of 0.4 %.

Fig. 1. Annual Forage Biomass Production (2002 – 2004)

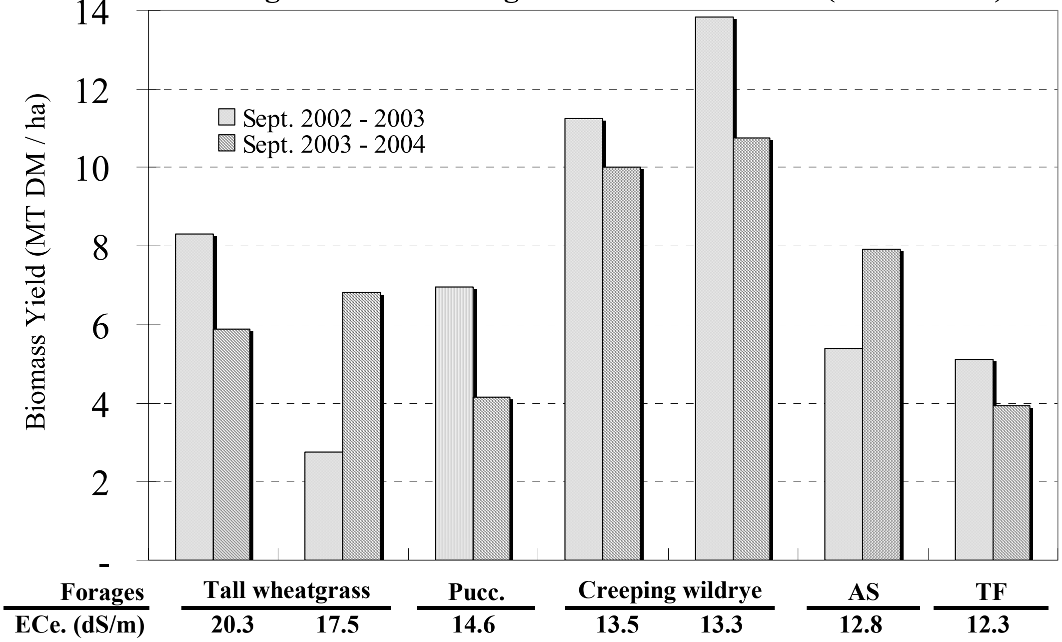


Table 1. Forage Quality and Ion Composition in field plots at RRR (Fall 2002 to 2003)

Forages	ECe	ME	CP	NDF	Ash	P	Ca	Mg	K	Na	S	NO_3-N	Se	Mo	B
	(dS/m)	MJ/kg DM		% DM				% DM					mg/kg DM		
Alf. *sal*	5.2	9.6	25	34	10.3	0.27	1.55	0.24	2.60	0.35	0.34	239	0.8	4.9	99
TF	12.3	9.1	18	53	10.8	0.16	0.35	0.18	1.64	1.15	0.48	163	**7.6**	3.8	1051
AS	12.8	7.0	13	71	8.7	0.10	0.49	0.18	1.96	0.15	0.44	50	**5.1**	2.1	327
CWR	13.3	7.8	14	64	7.9	0.12	0.33	0.13	1.95	0.28	0.36	50	**8.4**	1.4	305
"	13.5	7.9	16	63	8.3	0.17	0.31	0.10	2.49	0.14	0.21	130	**1.9**	1.4	174
Pucc.	14.6	8.6	18	61	8.5	0.20	0.27	0.12	2.34	0.60	0.28	100	**3.9**	0.8	58
TWG	17.5	9.1	15	57	9.9	0.18	0.21	0.11	1.72	0.78	0.29	110	**6.3**	1.7	418
"	20.3	8.7	10	60	7.0	0.11	0.25	0.14	1.41	1.04	0.38	50	**6.0**	1.3	557

Greenhouse Study

Under non-saline (NS) and low-saline (LS) irrigation, bermudagrass had the highest biomass production of all the forages (Fig. 2), but under high saline (HS) irrigation, its relative yield (RY) was less than 44 % (Fig. 3). *'Salado'* alfalfa also had high biomass production under NS irrigation, but under LS and HS irrigation, its RY was reduced to < 73%. Tall wheatgrass could be considered to be the most salt tolerant forage because under LS and HS irrigation, its relative yield was 94% and 87%, respectively, of the yield under NS irrigation. Paspalum was also quite tolerant to saline irrigation as shown by relative yields of 85% and 72% under LS and HS irrigation, respectively. CWR was intermediate in salt tolerance (Fig. 3).

Fig. 2. Biomass Production in Greenhouse Study

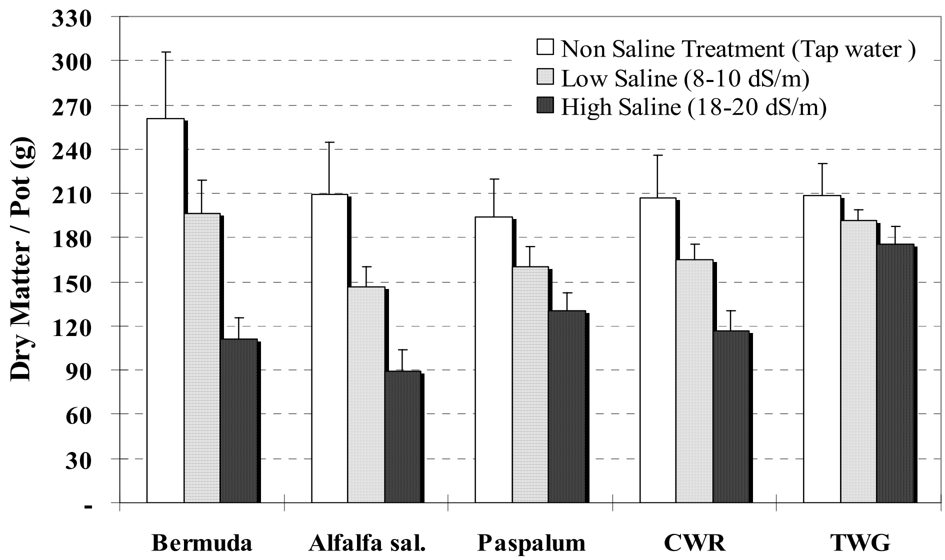
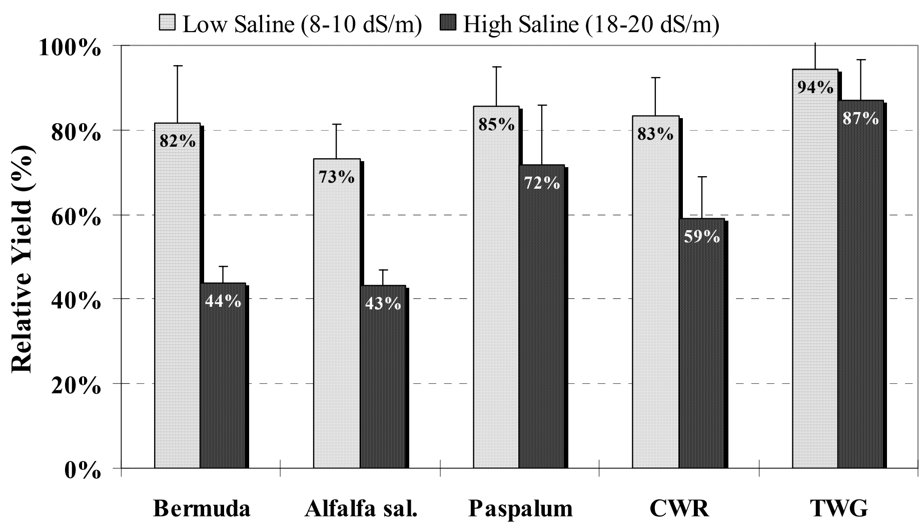


Fig. 3. Salt Tolerance (Relative Forage Yield) in Greenhouse Study



Conclusions

With the exception of alkali sacaton, the grass forages irrigated with saline DW at RRR have acceptable biomass production and forage quality. Selenium levels, however, are very high in these forages which will require care when being fed as hay or grazed by animals. *'Jose'* tall wheatgrass is considered to be the top candidate for DW re-use systems. When grown in a highly saline field (17.5 - 20.3 dS/m ECe), it had acceptable biomass production (6 to 8 MT/ha) and very good forage quality (ME > 8.7 MJ / kg DM). Tall wheatgrass also had the highest salt tolerance both in our greenhouse study (RY > 87% for LS & HS treatments) and in the sand tank study at the USSL (Grattan et al., 2004). Creeping wildrye is another good candidate: its forage quality was lower than for tall wheatgrass, but when grown in moderately saline fields (13 dS/m ECe) its biomass production was very high (10 – 13.8 MT/ha of DM). *'Alta'* tall fescue had high forage quality, but its productivity was moderate to low under high salinity in the field. This grass is suitable for irrigation with DW of lower salinity (C. Hurley, Panoche Drainage District).

In our greenhouse study, the productivity of bermudagrass and '*salado*' alfalfa was severely reduced by high saline irrigation (18-20 dS/m). Bermudagrass, however, has grown well at

Westlake Farms in soils averaging 13 dS/m ECe (S. Kaffka, personal communication). '*Salado*' alfalfa has grown well under less saline conditions; for example in a DW-irrigated field near Firebaugh (ECe = 5.2 to 6.4 dS/m) where it produced 13.8 MT/ha of DM (Baňuelos et al., 2003) At RRR, a '*Salado:801S'* mix in a FW-irrigated field (ECe = 5.2 dS/m) yielded 17.1 – 20 MT/ha of DM (data not shown) and it had the excellent forage quality (ME = 9.6 MJ/ kg DM)(Table 1).

Beef cattle grazing on creeping wildrye at RRR or fed hay from the DW-irrigated forage fields have had acceptable weight gains and reproductive success thus far. Future studies will monitor the health of these cattle and the response of the forages to grazing.

Acknowledgments

Valuable assistance was provided by John Diener, owner of Red Rock Ranch, and the CA Dept. of Water Resources. Research grants were awarded by the CSU Agricultural Research Initiative (ARI) and the Dept. of Water Resources, Proposition 204 Agricultural Drainage Program.

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Growing Broccoli with SustainGro™ Fertilizing System

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During Fall 2003, field tests were contracted at the Center of Irrigation Technology California State University at Fresno (CIT), to test on the efficacy of SustainGro™ Fertilizing System on broccoli. The farm compost and yeast based SustainGro™ , functions as a fertilizing system to release ammonia (NH_3), solubilize phosphorous (P) and potassium (K) from both the soil and the compost..

Broccoli, (*Brassica oleraceae, var* Marathon) was grown at a planting density of 64,586 plants per ha, on two rows/bed on a total of fifteen 1.52 m wide beds. Two equally sized blocks (419 m^2) were used to set 12 completely randomized plots in each block representing 4 treatments x 3 replicates. Tissue and soil sampling were carried out from within the central area of the plot identified for yield measurements.

Generally the nutrient levels (N, P, K, Zn) determined in the leaves during the growing season were within the sufficiency ranges. Of the four treatments tested, the treatment comprising of the application a combination of pre-plant phosphorus, 900kg/ha of compost, 53 kg/ha of N as chemical fertilizers and 600 kg/ha of SustainGro™ appeared to be the optimum treatment. With a total N input at only 52% of the grower practice, the comparable yield shows the nutrient release efficiency from SustainGro™.

Data collected from an experiment aimed at examining the efficacy of the SustainGro™ on the yield and quality of bell peppers grown in California is currently being analyzed. Future studies should focus on determining the optimum application rate and environmental effects of the SustainGro™ products.

Reducing Non-point DOC and N Exports with Rice in the Delta

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California's growing population continues to stress water supplies resulting in water quality and supply conflicts among end-users. Agricultural activities are thought to decrease water quality by elevating levels of dissolved organic carbon (DOC) and nitrogen (N) in irrigation return waters in the form of crop residues and decomposed soil organic matter. DOC poses potentially serious health concerns when Delta waters are used as drinking water, since disinfection through ozone or chlorination is required for virtually all domestic waters derived from surface waters, during which DOC and bromide form disinfectant bi-products (DBP's). Trihalomethane (THMs) and haloacetic acids (HAAs) are the most abundant byproducts formed, both of which are carcinogenic and mutagenic and thus strictly regulated by the U.S.E.P.A. CALFED recognizes this serious health issue and aims to provide safe, reliable, and affordable drinking water from the Delta, to be achieved through a cost-effective combination of alternative source waters, source control, and treatment technologies.

One option for reducing DOC in Delta water is through agricultural land management. Delta lands can be maintained in current dry-land row-cropping systems, up to 35,000 acres can be retired and converted to wetland and riparian habitat, or existing row-crop land can be converted to another use such as rice production. Rice production is desirable because of waterfowl habitat benefits and subsidence mitigation. Rice is the only major land conversion under consideration for which the potential water quality impacts need to be determined.

California rice growers produce the highest annual rice yields in the world thanks to implementation of sophisticated best management practices (BMPs). Intensive rice production has both positive and negative environmental consequences. Up to 3-5 tons of carbon are returned to soils annually through rice production, and 40-60% of that mass persists the following year increasing soil organic carbon content over many years. This benefit could reverse the soil carbon depletion over the past 100 years, which has resulted in severe subsidence (up to 20 feet) largely through soil oxidation. The USGS has demonstrated that wetlands can reverse subsidence. Additionally rice production in the delta may have direct economic incentives as shown by pilot studies in the eastern Delta.

DOC may be an issue with rice production since due to the large amounts of straw persisting in the soils each year, DOC concentrations in groundwater may be higher than background levels. Rice may be more prone than natural wetlands to release DOC because of associated soil preparation and draining activities. Given the acreage under rice production this is potentially a non-point source for DOC.

Nitrogen is another potential water quality problem. N fertilizer is essential for nearly all commercial rice production in California. Rice straw incorporation can reduce fertilizer N by increasing available soil N. N is often a limiting nutrient in aquatic systems, and if N exports significantly increase N concentrations within the Delta and in upstream rivers, then problems such as greater algal blooms that create increased DOC, dissolved oxygen depletion, and taste and odor problems, will be exacerbated.

Ultimately this project seeks to improve drinking water at the tap. We have converted approximately 150 acres of Delta cornfields to rice fields managed under a variety of BMPs, on which DOC and N exports will be characterized over approximately two years. This study will enable us to assess the impacts of different rice production BMPs on DOC and N exports from rice fields. Delta farms were selected based on their BMPs (eg. hydrology, straw management, covercrops) and the Delta was specifically targeted because conversion to rice there will likely have the greatest environmental benefits (decreasing DOC exports and mitigate subsidence). At all sites inflow and outflow DOC and N concentrations will be sampled and soil chemistry will be characterized. Inflow, outflow, and groundwater DOC, DBP, and N species concentrations will be monitored for different BMPs. Treatments have been replicated at two different farms. Monitoring is designed to capture water quality changes during periods of BMP implementation, and a relationship between BMP and resulting outflow water quality will be developed. We anticipate that rice production will reduce DOC exports, and additionally DOC and N exports will vary with different BMPs.

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Changes in Aggregate-Protected Carbon with Conservation Tillage and Cover Cropping

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Conservation tillage (CT) and cover cropping are sustainable agricultural practices that may provide solutions for California's declining soil, air and water quality. These practices can increase soil organic matter, reduce dust production conserve water and increase soil C. We looked at changes in total soil C and particulate organic matter (POM) within three physical fractions: free POM, microaggregate protected POM, and mineral associated organic matter. With the decrease in soil disturbance under CT and increased C inputs with cover cropping, we expect microaggregate protected POM to increase in both the CT and the cover crop treatments over the long term. Increases in microaggregate protected POM may indicate future C storage. Initial inspection of soil C numbers suggest that cover cropping increases total soil C in both CT and standard tillage on the order of 4500 kg C/ha in the top 30 cm over a 4-year period. In the CT treatments, the increase occurred in the surface 15 cm, while in the standard tillage treatments, it was distributed throughout the top 30 cm. In the treatments without cover crops, there was no change in soil C in the 0-15 cm depth and an overall loss in the 15-30 cm depth, ~1000 kg C/ha in standard tillage and ~2000 kg C/ha in CT. In dry hot irrigated systems, cover cropping was more important for soil C accumulation than tillage practice.

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California Chapter – American Society of Agronomy
2005 Plant and Soil Conference Evaluation

Chapter web site**:** ***http://calasa.ucdavis.edu*****.**

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Conference provided useful information	1	2	3	4	5
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2. What session topics do you recommend for future conferences?

a. ____

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a. ____

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5 Please rank your preference for the location of next year's conference. (Use 1 for first choice, 2 for second, etc.)

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