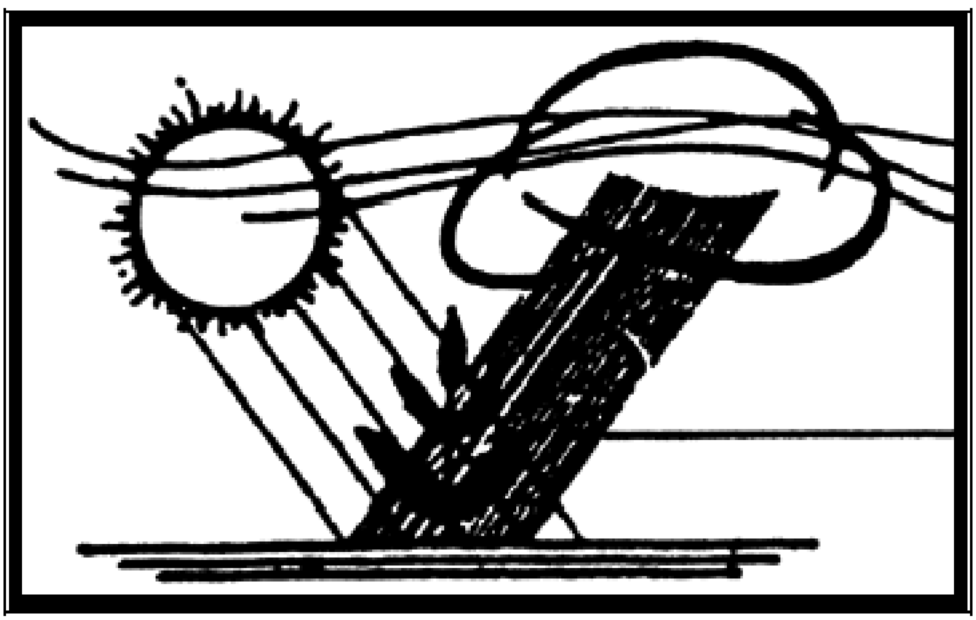
CONFERENCE PROCEEDINGS

2008
California Plant and Soil Conference

Conservation of Agricultural Resources



California Chapter of the American Society of Agronomy

Co-sponsored by the California Plant Health Association

February 5 & 6, 2008

Holiday Inn
9000 W Airport Dr
Visalia, CA 93277

To download additional copies of the proceedings or learn about the activities of the California Chapter of the American Society of Agronomy, visit the Chapter's web site at: http://calasa.ucdavis.edu

CALIFORNIA PLANT & SOIL CONFERENCE
CONSERVATION OF AGRICULTURAL RESOURCES

TUESDAY, FEBRUARY 5, 2008

10:00 **General Session Introduction** – Session Chair & Chapter President – Ben Nydam, Dellavalle Labs

10:10 **California Water Wars – Can We Reverse the Tide –** Bill Phillamore, Paramount Farming Co.

10:40 **Implementation of San Joaquin River Settlement** – Ron Jacbosma, General Manager, Friant Water Users Authority

1:10 **Who's Driving the Bus – Driving Forces Behind Food Safety Issues –** Ted Batkin, President, Citrus Research Board

11:40 Discussion

12:00 **Western Plant Health Luncheon Speaker:** Carl Winter, Director of FoodSafe Program, Ext. Food Toxicologist, UC Davis "Staying Alive—A Musical Look At Contemporary Food Safety Issues"

CONCURRENT SESSIONS (PM)

I. Spray Technology

1:30 Introduction – Session Chairs: **Ben Faber**, UCCE Ventura Co.; **Dave Woodruff**, Woodruff Ag Consulting.

1:40 **Plant Growth Hormones and the Use of Synthetic Growth Regulators in Horticultural Crops** – Don Merhaut, UC Riverside

2:00 **Uses Of Plant Growth Regulators In Tree Nut Crops** – Bob Beede, UCCE, Kings County

2:20 **Spray Technology –** Jim Coburn, Western Farm Service, Fresno, CA

2:40 Discussion

3:00 BREAK

3:20 **Zinc Movement and Distribution within a Peach Tree –** Scott Johnson, Extension Promologist, UC Kearney Agricultural Center, Parlier, CA

3:40 **Considerations in Effective Spray Coverage –** Neil O'Connell, UCCE Tulare County

4:00 **Where PGRs Are Going? –** Jim McFerson, WA Tree Fruit Research Commission

4:20 Discussion

4:30 **ADJOURN**

II. Water Supply/Irrigation/Water Quality

1:30 Introduction – Session Chairs: **Al Vargas,** CDFA**; Blake Sanden**, UCCE Kern Co.

1:40 **Spatial and Temporal Trends in Nitrate Concetration in the Eastern San Joaquin Valley Regional Aquifer and Implications for Nitrogen Fertilizer Management –** Karen Burow, USGS, Sacramento, CA

2:00 **Assessing Nitrate Leaching Potential by Hazard Index –** Laosheng Wu, UC Riverside

2:20 **GIS/Aerial Imagery Applications –** Tim Stone, Britz Fertilizers

2:40 Discussion

3:00 BREAK

3:20 **Modern Concepts in the Management of Saline Soils and Irrigation Supplies** - Don Suarez, USDA Salinity Lab, Riverside, CA

3:40 **Is Drip Irrigation Sustainable Under the Shallow, Saline Ground Water Conditions of the San Joaquin Valley? –** Blaine Hanson, UC Davis

4:00 **Pistachio Salinity Tolerance and Development with Interplanted Cotton –** Blake Sanden, UCCE, Kern County

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 6, 2008
CONCURRENT SESSIONS (AM)

III. Pest Management

8:30 **Introduction** – Session Chair: **Tom Babb,** CA DPR

8:40 **Department of Pesticide Regulation's Environmental Justice Pilot Project –** Pat Matteson, CDPR, Sacramento, CA

9:00 **A Recently Introduced Pest: The Light Brown Apple Moth –** William Roltsch, CDFA, Sacramento, CA

9:20 **Managing Diaprepes Root Weevil, a Polyphagous Pest –** Kris Godfrey, CDFA, Sacramento, CA

9:40 Discussion

10:00 BREAK

10:20 **Funding Opportunities for Farmers and Ranchers (EQIP) –** Alan Forkey, USDA-NRCS, Davis, CA

10:40 **Third Party Certification for Pest Management Practices –** Dan Sonke, Protected harvest, San Diego CA

11:00 **New Low Risk Pest Control Products –** Pam Marrone, CEO/Founder Marrone Organic Innovations, Inc., Davis CA

11:20 Discussion

IV. Maintaining Soil Resources

8:30 **Introduction** – Session Chairs: **Suduan Gao**, USDA-ARS; **Rob Mikklesen**, IPNI

8:40 **Sustaining Soils, Sustaining Society –** Michael J. Singer, UC Davis

9:00 **Salt Management: A Key to Irrigation Sustainability in Arid Climates –** J.D. (Jim) Oster, UC Riverside

9:20 **Challenges on Salinity Management in Irrigated Agriculture in California –** Steve R. Grattan, UC Davis

9:40 Discussion

10:00 BREAK

10:20 **The Role of Private Land Trusts in Maintaining Soil Resources –** Hillary Dustin, Land Steward, Sequoia Riverlands

10:40 **Soil Properties Influenced and Altered by Agricultural Operations in California's Great Central Valley** – Kerry D. Arroues, USDA-NRCS

11:00 **A Systems Approach to Conservation Tillage and Nutrient Management in the production of Dairy Forages** – Dino Giacomazzi, Kings County Farm Bureau

11:20 Discussion

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

CONCURRENT SESSIONS (PM)

V. Plant & Soil Nutrition

1:30 **Introduction –** Session Chairs: **Joe Fabry**, Fabry Ag Consulting; **Will Horwath**, UC Davis-LAWR

1:40 **N&P, High or Low in Drip Irrigated Vegetables** – Don May, UCCE, Fresno County

2:00 **Boron Nutrition of Grapevines –** W.L. Peacock, UCCE, Tulare County

2:20 **Evaluation of the Amino Sugar Soil Test for Available** N – William Horwath, UC Davis

2:40 **Mineralization of Nitrogen in Liquid and Solid Dairy Manures Applied to Soil –** Stuart Pettygrove and Aaron Heinrich, UC Davis

3:00 Discussion

3:20 **ADJOURN**

VI. Food Safety

1:30 **Introduction –** Session Chairs: **Al Vargas**, CDFA; **Joe Voth**, Grimmway Farms

1:40 **Fate of Pathogens in the Environment and Implications in the Primary Production Chain of Fresh Produce** – Dr. Mark Ibekwe, USDA-ARS

2:00 **Practical Food Safety Guidelines on the Farm –** Dr. Trevor Suslow, University of California Davis

2:20 **Food Safety and the Environment: Exploring How Food Safety Concerns are Impacting Grower Efforts to Protect the Environment** – Melanie Beretti, R C D, Monetrey County

2:40 **Development of the Lettuce and Leafy Green Agreement** – Hank Glicas, Western Growers Association

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
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1982	Carl Spiva
1983	Kent Tyler
1984	Dick Thorup
1985	Burl Meek
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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
2005	Bruce Roberts
2006	Will Horwath

California Chapter of American Society of Agronomy

Past Honorees

Year	Honoree	Year	Honoree
1973	J. Earl Coke	1997	Jolly Batcheller
1974	W.B. Camp		Hubert B. Cooper, Jr.
1975	Milton D. Miller		Joseph Smith
	Ichiro “Ike” Kawaguchi	1998	Bill Isom
1976	Malcom H. McVickar		George Johannessen
	Perry R. Stout	1999	Bill Fisher
1977	Henry A. Jones		Bob Ball
1978	Warren E. Schoonover		Owen Rice
1979	R. Earl Storie	2000	Don Grimes
1980	Bertil A. Krantz		Claude Phene
1981	R. L. “Lucky” Luckhardt		A.E. “Al” Ludwick
1982	R. Merton Love	2001	Cal Qualset
1983	Paul F. Knowles		James R. Rhoades
	Iver Johnson		Carl Spiva
1984	Hans Jenny	2002	Emmanuel Esptein
	George R. Hawkes		Vince Petrucci
1985	Albert Ulrich		Ken Tanji
1986	Robert M. Hagan	2003	Vashek Cervinka
1987	Oscar A. Lorenz		Richard Rominger
1988	Duane S. Mikkelsen		W. A. Williams
1989	Donald Smith	2004	Harry Agamalian
	F. Jack Hills		Jim Brownell
1990	Parker F. Pratt		Fred Starrh
1991	Francis E. Broadbent	2005	Wayne Biehler
	Robert D. Whiting		Mike Reisenauer
	Eduardo Apodaca		Charles Schaller
1992	Robert S. Ayers	2006	John Letey, Jr.
	Richard M. Thorup		Joseph B. Summers
1993	Howard L. Carnahan	2007	Norman Macillivray
	Tom W. Embelton		William Pruitt
	John L. Merriam		J.D. (Jim) Oster
1994	George V. Ferry	2008	**V. T. Walhood**
	John H. Turner		**Vern Marble**
	James T. Thorup		**Catherine M. Grieve**
1995	Leslie K. Stromberg		
	Jack Stone		
1996	Henry Voss		
	Audy Bell		

California Chapter
American Society of Agronomy

2008 Chapter Board Members

Executive Committee

President Ben Nydam, Dellavalle Laboratory, Inc.
First Vice President Tom Babb, CA Dept. Pesticide Regulation
Second Vice President Joe Fabry, Fabry Ag Consulting
Secretary-Treasurer Larry Schwankl, UC Davis
Past President William Horwath, Dept. of Land, Air & Water Resources, UC Davis

Governing Board Members

One-year term	Charles Krauter, CSU Fresno Al Vargas, CA Dept. Food & AG Dave Woodruff, Woodruff Ag Consulting
Two-year term	Suduan Gao, USDA - ARS Blake Sanden, UCCE, Kern County Robert Mikkelsen, Potash & Phosphate Institute
Three-year term	Ben Faber, UCCE, Ventura County Joe Voth, Grimmway Farms, Arvin, CA.xx
Advisor	Casey Walsh Cady, California Dept of Food and Agriculture

2007 Honorees

Vern Marble

V.T. Walhood

Catherine M. Grieve

Dr. Vern Marble

It is with great pleasure that Dr. Vern Marble is presented as an honoree by the California Plant and Soils Conference.

Dr. Marble has been known for many years as 'Mr. Alfalfa' in California. He is a true leader for forages.

Vern was instrumental at promoting the introduction of multiple pest resistant varieties, particularly CUF 101 in the 1970s and 80s, which had a tremendous impact on California producers and on alfalfa producers worldwide, including Argentina, Middle East, and Australia. These introductions were nothing short of revolutionary. He has promoting standardization, co-founding the National Forage Testing Association (NFTA) in the 1980s. Dr. Marble has served as a mentor to countless numbers of Farm Advisors and Agricultural Experiment Station scientists. For 50 years, everyone working with alfalfa in California has benefited from Vern's gentle guidance and council.

Vern was born in Tremonton, Utah in 1928 and moved with his family four years later to Fillmore, Utah where his father taught Vocational Agriculture. Vern had his first introduction to farm life when at the age of 13 he went to work for his grandfather and uncle on the family farm near the Utah/Idaho border, being paid the handsome sum of $3 per day. Vern received a B.S. and M. S. degree from Utah State University in Logan and in 1957 completed his PhD in Plant Physiology at UC Davis and subsequently accepted a position at Davis. Dr. Vern L. Marble retired September 30th 1991 after 34 years service with the University of California, Davis, as Cooperative Extension Forage Specialist.

Dr. Marble has been author or co-author of over 230 popular and technical publications during his career while providing statewide leadership to the important alfalfa hay and seed production industry. An important part of his applied research was on alfalfa varietal evaluation and production of high quality hay and seed. During his career, Dr. Marble has been a consultant in more than a dozen foreign countries.

Vern believes that his greatest fulfillment and personal reward has come from working with the many UC Cooperative Extension Farm Advisors with their unique ability to identify and solve problems of great importance to the agricultural community. The Farm Advisors would tell you that much of their success comes from the teachings of Dr. Marble.

We can think of no one more deserving of this dedication and honor than Vern Marble, who has contributed much to California agriculture. Vern, we salute you and thank you for your tremendous contribution. Congratulations.

Dr. V.T. Walhood

Dr. Walhood has spent 60 years (1948 - 2008) of research on growth and development of the cotton plant under irrigated agriculture in the Far West. During those years he conducted extensive research programs on chemical and cultural growth regulation of the cotton plant almost entirely under field conditions.

Dr Walhood was born in 1922 and raised on a farm in North Dakota, enduring the great drought and depression of the 30Õs. He was educated in a one room rural school and high school in Pekin, ND. In 1939 he entered the Agronomy Department at North Dakota State University (NDSU). In 1942 he volunteered for military service. As a combat infantry platoon leader in WWII he was awarded: the Bronze Star in the Battle of Wingen-sur-Moder, France, the Purple Heart and Silver Star in the siege of Forbach, France, the Combat Infantry Badge, and 3 Battle Stars for combat in France and Germany.

In 1946, VT was discharged from the military and returned to NDSU. He received his BS in Agronomy in 1948 and was an Assistant in Agronomy Department, assisting in corn breeding.

He began his research on harvest aids in cotton on the Pima Indian Reservation at the USDA Cotton Research Station, Sacaton, AZ., in 1948. In 1951, VT began graduate studies at University of California, Los Angeles in botanical sciences and received his PhD from UCLA in 1955. From 1956-81 he was involved in physiological studies on cotton harvest aids, seed quality and chemical growth regulators at the USDA Cotton Research Station, Shafter, Ca. He was also an Associate in Agronomy with UC Davis. He spent his sabbatical time during 1961 & 1962 at the University of Cairo researching reddening disease in ELS cotton for the UN Food & Ag program. VT returned to the USDA and his research with mepiquat chloride, PIX, led to its development in the 70's as a growth regulator in cotton. VT did pioneering studies on the use of ethylene (Prep, etc.) to increase the rate of boll opening and leaf abscission in the cotton harvest aid program. VT was a pioneer researcher on development of narrow-row cotton production systems. He also developed techniques that improved seed set in difficult to make cotton crosses by using gibberellins.

In 1981, VT became a private consultant in the area of chemical growth regulation, grower cotton production systems and breeding of Pima and Acala varieties for specific growing conditions. He has also been a consultant for Chico State University, Plant Science Department, on cotton production in the Sacramento Valley. He patented the first privately developed cotton variety (Acala M5) approved for release by the Acala Cotton Board.

VT Walhood has published over 100 scientific papers and abstracts on harvest aids research and agronomic practices to maintain cotton fiber quality and production. He was given the first copy of Cotton Physiology, the first in a series of reference books published by the Cotton Foundation in recognition of his research.

Dr. Catherine M. Grieve

Catherine Grieve was born in Adams Center, New York, a small rural town (population 800) located close to the St. Lawrence River and Ontario, Canada. Catherine's father worked for the railroad, but both parents were avid gardeners growing vegetables, berries, and flowers.

Catherine received her B.S. in Chemistry from St. Lawrence, University in New York. She worked as a technical writer, and later as a chemist for 16 years, at the U.S. Naval Ordnance Laboratory in Corona, CA. What might have been the best "bad event" to happen to Catherine was that the naval base closed, thus prompting her to return to school after thirty years and complete her Ph.D. in Botany at the University of California, Riverside. Thereafter, and to the present, Catherine Grieve has worked for the USDA-ARS Salinity Laboratory in Riverside, CA. She worked as a plant physiologist for 20 years, as Acting Research Leader or Research Leader for the Plant Sciences group for five years, and now again as a research plant physiologist.

Over the course of her illustrious career at the Salinity Lab, Catherine Grieve has authored or co-authored more than 150 scientific articles and book chapters. She is co-inventor on 7 U.S. patents. Catherine is internationally recognized for her work in salinity-plant interactions, particularly in the area of mineral nutrition.

Catherine's strong knowledge of mineral nutrition in plants led her and her colleagues to recognize the need to evaluate crop response to salinity using solutions of ionic compositions that mimic the degraded waters present in different agricultural areas of California, such as (1) saline drainage effluents present in the San Joaquin Valley, (2) recycled tailwaters in the southern inland valleys, (3) coastal well waters contaminated by seawater. Still today, many other labs continue to conduct salinity research using standard sodium chloride solutions.

Additional research interests of Catherine's include the development of models to predict the effects of salinity on ion relations, growth, quality, and yield parameters in crops; development of strategies for reuse and management of saline drainage effluents and wastewaters containing potentially toxic trace elements (boron, selenium, molybdenum); and the identification of agronomic, horticultural crops suitable for use in water reuse systems. Most recently, Catherine has been conducting salt tolerance evaluations of high-value specialty crops such as conventional and Asian vegetables, strawberry, landscape plants and commercially important cut flowers (snapdragon, statice, stock, zinnia, lisianthus, poinsettia, marigold, ranunculus).

Catherine Grieve's colleagues describe her as one of the most conscientious and meticulous scientists ever encountered. Not only are her experiments well-designed and run with care, she rigorously evaluates the data and puts a substantial amount of time and care in manuscript preparation. To quote, "*Each word is selected perfectly. Moreover, she is enthusiastic about her work and loves to share her results and conclusions with collaborators around the world*."

Catherine is a young-at-heart, curious-in-mind, hard-working individual with compassion, who is most deserving of this recognition. Her contributions to agriculture extend well beyond the borders of California, and are recognized world-wide. Catherine, we salute you,

2008 Scholarship Recipient and Essay

Essay question:

*Must Farming Conflict With Conservation***?**

Scholarship Committee:

Suduan Gao
Ben Faber
Carol Frate
Blake Sanden

2008 Winning Scholarship Essay (First Place)

James M. Johnson
California State University, Fresno

Must Farming Conflict With Conservation?

As the total acreage utilized for farm practices is steadily declining and the world's population and demand for agricultural products is greatly increasing, farming must coexist with conservation in order to sustain agricultural production in the wake of growing environmental concerns, reduced land availability, and limited water resources. Thus, it is not a question of whether farming must conflict with conservation but rather how they coexist and evolve into modern sustainable practices.

The evolution of technology toward mechanization in farm practices as well as burning of agricultural waste has led to the concern for air quality and the need for solutions. The use of cleaner burning engines and fuel, under EPA guidelines, has the ability to reduce the overall impact on air quality. The utilization of plant biomass for compost and soil cover not only reduces environmental impacts on air quality but soil conservation as well. Other agronomical practices including reduced tillage and no tillage is aimed at reducing the amount of volatile organic compounds emitted into the atmosphere. These are only a few of the practices implemented in relation to air quality that are currently reducing agriculture's overall impact.

Soil conservation and soil reclamation is also of major significance as it prevents the need for migration of agriculture onto wildlife habitats. The reclamation of agricultural lands via the utilization of crop residue and soil microbes aids in soil nutrient availability via the microbial breakdown of crop residue and the replenishment of soil nutrients. On those lands greatly devastated by alkalinity, the use of soil amendments and water to leach salts and replenish soil fertility as well as salt tolerant crops that have the ability to uptake large quantities of salts are utilized to reclaim those agricultural lands. Soil conservation can be sustained through the use of cover crops and reduced/no tillage. Cover crops not only aid in reduction of soil runoff but also add to the soil nutrient content, improve soil tilth as well as a weed suppression mechanism. Reduced and no till systems reduce the agricultural impact by reducing soil compaction as well as air pollution in the form of fuel emissions and dust.

Water allocation and quality is a key factor as the conservation of water impacts not only agricultural practices but the entire hydraulic ecosystem. The proper use of agricultural chemicals has been greatly regulated to reduce the possibility of water and soil contamination. The utilization of drip systems has increased the irrigation efficiency and reduced the overall use of water in regard to agricultural systems. The use of water in rice production has also been a great conservation effort as it can be used as not only a weed control mechanism but as a wetland for waterfowl.

The implementations of these techniques are prime examples of conservation practices directly related to agriculture. They each reduce the overall impact to the ecosystem in a systematic approach that takes into account the need to maintain crop yields. However, these practices must be utilized on a large scale to significantly reduce the overall agricultural impact on the environment and the conservation of our ecosystem.

2008 Winning Scholarship Essay (Second Place)

Caitlin E. Lawrence
California Polytechnic State University, San Luis Obispo

<u>Do Farming and Conservation Have to Conflict?</u>

An agriculture instructor once told me that a good agriculturalist is a good environmentalist. This statement is true now more that ever. For as long as there has been agriculture and those concerned about conservation, there has been conflict of some sort; however in the modern world, farming does not need to conflict with conservation. Modern technological advances have allowed agriculturists all over the world to maintain a way of life and protect the environment simultaneously. Holistic management and utilizing modern farming methods can mean that agriculturalists can preserve a way of life while maintaining and protecting the environment.

In the modern world of agriculture, holistic management can mean a way of life when it comes to producing the world's food. This style of farming seeks to maintain and enhance the economic, social, and environmental status quo. The harmony of these three aspects is what promotes the production of the food and fiber that agriculturalists need to survive, but it also promotes the protection of the environment. Making sure that agriculturalists are able to make a profit and keep farming as a career, ensuring that the community understands the importance of agriculture, and ensuring the quality of the environment for future generations is what holistic management is trying to promote. By practicing holistic management, agriculture and conservation do not need to conflict, but they can learn and thrive from one another.

Modern technological advances have placed agriculture in a position to sustain the world's food and fiber needs as well as maintain a healthy environment. With the introduction of GPS navigated tractors and precision placed fertilizers and herbicides, the environment has benefited in more ways than one. By precision farming, runoff contamination from excess fertilizers and herbicides can be minimized, if not eliminated. Soil compaction from being driven on continuously can also be minimized by tractors maintaining constant paths. Technology and common sense have been combined in modern fields to create an environment that can sustain agriculture, and itself. Conscientious farming can lead to an era that combines effective farming techniques as well as a healthy environment.

By ensuring that agriculture and the environment have a future, they do not have to conflict. Holistic management and modern technological advances have created a world where agriculture can benefit the environment, and the environment can sustain agriculture. These advances will drive a future where agriculture and conservation will compliment each other, not conflict with one another.

General Session

California Water Wars - Reversing the Tide

William D. Phillimore, Executive Vice President, Paramount Farming Company
33141 E. Lerdo Highway, Bakersfield, CA 93308
Phone (661) 399-44565, Fax (661) 399-1735, wdp@paramountfarming.com

Presentation Outline

The Public's Perception of Agriculture

Agriculture's Cocoon

Reality for Water Users

Sacramento/San Joaquin Delta

California Governance

Required Action

Sources

ACWA
California Farm Bureau
California Farm Water Coalition
California Water Awareness Campaign
Sustainabledelta.com

Implementation of the San Joaquin River Settlement

Ronald D. Jacobsma, Consulting General Manager, Friant Water Users Authority,
854 N. Harvard Avenue, Lindsay, CA 93247
Phone (559) 562-6305, FAX (559) 562-3496, rjacobsma@friantwater.org
Additional information available at: www.fwua.org

Summary

The litigation entitled *Natural Resources Defense Council, et al.* v. *Kirk Rodgers, et al.* was settled on September 13, 2006. A coalition of 14 environmental and fishing groups filed the lawsuit in 1988. The named defendants were the Departments of Interior and Commerce. The Friant Water Users Authority and a number of its members joined the suit as defendant-intervenors.

The Settlement includes two objectives. The first is a commitment to restore flows and salmon to the San Joaquin River between Friant Dam and the Merced River confluence. The settlement also recognizes that water is the lifeblood for both salmon and the people of the San Joaquin Valley – it is a resource that must be shared. Thus, the settlement also provides opportunities for Friant Division long-term water contractors to mitigate water supply impacts resulting from water releases called for under the Settlement.

Introduction

By 1920, agricultural development in the Friant service area had exhausted local water resources, particularly groundwater. This caused a severe water crisis in the area between Madera County and the Tehachapis, which threatened the reversion of hundreds of thousands of acres of farmland back into desert. In 1931, the California Water Plan was submitted to the State Legislature. The Plan called for construction of the Central Valley Project, which included construction of Friant Dam on the San Joaquin River. In addition, the Plan called for construction of the Madera and Friant-Kern Canals so that the water impounded by Friant Dam could be diverted to the Friant service area. The Plan envisioned that in many years, stretches of the San Joaquin River below Friant Dam would be dry. Construction of Shasta Dam was also part of the Plan. It would allow Sacramento River water to be imported to the northern San Joaquin Valley, replacing the San Joaquin River water that had historically been used north of Mendota Pool. The State of California enacted the California Central Valley Project Act, but California was unable to fund construction of the CVP due to the Great Depression. California then asked the federal government for help in completing the Water Plan. The CVP became a federal project and the Bureau of Reclamation, an agency of the Interior Department, was directed to construct it.

In the late 1980s, irrigation districts within the Friant Division were moving to renew long-term water service contracts that were then expiring. Friant districts believed the United States had pledged when it executed the original 40-year contracts that there would be a continuous supply of water for Friant as long as it was put to beneficial use. In 1988, as the United States Department of the Interior was in the process of renewing the first Friant contract, that of the Orange Cove Irrigation District, objections were raised by the environmental community. The Natural Resources Defense Council (NRDC) and a coalition of other environmental and commercial fishing plaintiffs initiated litigation that challenged the contract renewals. Since then, the environmentalists amended their complaint several times, raising many complicated legal issues.

In the mid 1990's, the dispute centered on Section 5937 of the California Fish & Game Code. This law requires dam owners and operators to release "sufficient" water to operate a fish passageway or "maintain in good condition" the fish in the river below the dam. The issue was whether this state law applied to the federal project and, if so, whether releasing the amount of water needed to satisfy the state law would conflict with the laws authorizing the dam. In August 2004, the court ruled that Section 5937 imposed a continuing duty to release sufficient water from Friant Dam into the San Joaquin River to restore former historic salmon runs and fishery conditions. The court did not determine how much water would be needed to satisfy the state law. Rather, the court set the case for a trial in February 2006 to determine the amount of the releases. In 2005, the parties began preparing for that trial and gained valuable new scientific information about possible restoration strategies.

In the summer of 2005, Senator Dianne Feinstein and House Water and Power Subcommittee Chairman George Radanovich began a nonpartisan effort to bring the parties together to achieve a mutually agreeable settlement. This represented the second try to settle the case. The first set of settlement negotiations took place in 1999 - 2002, during which time the parties conducted many fishery and water supply related studies. Even though this first four year round of negotiations proved unsuccessful with the parties ending up going back to court, a foundation for future discussions was laid.

New negotiations began during the summer of 2005, and by April 2006, the parties were able to inform the court that agreement had been achieved on numerous issues. At the end of June, attorneys for the parties reported that they had agreed to a settlement in principle and the Stipulation of Settlement was filed on September 13, 2006.

The Settlement

The Settlement Agreement is based on two goals and objectives: a restored river with continuous flows to the Sacramento-San Joaquin River Delta and naturally reproducing populations of Chinook salmon; and a water management program to minimize water supply impacts to San Joaquin River water users. The Settling Parties will work together on a series of projects to improve the river channel in order to restore and maintain healthy salmon populations. Flow restoration is to be coordinated with these channel improvements, with spring and fall run Chinook salmon populations reintroduced in approximately six years. At the same time, the Settlement limits water supply impacts to Friant Division long-term water contractors by providing for new water management measures that are to be undertaken by the U.S. Bureau of Reclamation. The Settling Parties believe that commitments under the agreement and the cooperative approach toward restoration provide an historic opportunity to restore the San Joaquin River in a manner broadly acceptable to water contractors who have been operating under a cloud of uncertainty regarding their water supply due to pending litigation for the past 18 years. The agreement provides that long-term Friant Division water service contracts be amended to conform the contracts to the terms of the settlement. It also includes draft federal legislation authorizing the Departments of the Interior and Commerce to implement the settlement.

Restoration Goal

At the heart of the settlement is a commitment to provide continuous flows in the San Joaquin River to sustain naturally reproducing Chinook salmon and other fish populations in the 153-mile stretch of the river between Friant Dam and the Merced River. Accomplishing this goal will require funding and constructing extensive channel and structural improvements in many areas of the river, including some that have been without flows (except for occasional flood releases) for decades.

Water Management Goal

Recognizing that the settlement's restoration flows will reduce the amount of water available for diversion at Friant Dam. The settlement also includes provisions to protect water availability for the 15,000 small farms that currently rely on these supplies. One million acres of the most productive farmland in the country as well as many towns and cities along the southern San Joaquin Valley's East Side receive all or a major portion of their water supplies from Friant Dam. The settlement recognizes the importance of this water to those farms and calls for development of water management solutions to provide these users water supply certainty for the long term. Such a program would include a flexible combination of recirculation, recapture, reuse, exchange and/or transfer programs. Additional storage such as groundwater banking will also be explored.

Phased Approach

Restoring continuous flows to the approximately 60 miles of dry River will take place in a phased manner. Planning, design work, and environmental reviews will begin immediately, and interim flows for experimental purposes will start in 2009. The flows will be increased gradually over the next several years, with salmon being reintroduced by December 31, 2012. The settlement continues in effect until 2026, with the U.S. District Court retaining jurisdiction to resolve disputes and enforce the settlement. After 2026, the court, in conjunction with the California State Water Resources Control Board, would consider any requests by the parties for changes to the restoration program.

Restoration Funding

The settling parties have carefully studied San Joaquin River restoration for many years, and as part of the settlement have identified the actions and highest priority projects necessary to achieve the restoration goal. These include expanding channel capacity, improving levees, and making modifications necessary to provide fish passage through or around certain structures in the river channel. The settlement identifies a number of funding sources to support implementation of these projects, including current environmental contributions from farmers and cities served by Friant Dam, state bond initiatives and authorization for federal contributions.

More specifically, the settlement dedicates the "Friant Surcharge", a Central Valley Project Improvement Act (CVPIA) environmental fee of $7 per acre foot of water delivered to Friant Contractors that is expected to average about $8 million per year, and up to $2 million of other Restoration Fund Payments annually made by water users under the CVPIA for use by the program. It also dedicates the capital component of water rates paid by Friant Division water users to the program for nine years and permits settlement monies to be used for the Water Management and Restoration goals. Ongoing Friant program contributions are committed and capped at current Restoration Fund and Surcharge Payment levels. Enactment of the authorizing legislation in conjunction with the settlement could make an additional $250 million in federal contributions available. The settlement provides for bonding, guaranteed loans or other financing using annual payments for debt service. It anticipates fiscal participation by the State of California, as well.

Impacts

The Friant Water Users Authority agreed to the settlement because it provides certainty with respect to water supply impacts and monetary impacts. There was concern that an adverse ruling from the Court would result in large amounts of water being dedicated to the restoration of the fishery and therefore lost for agricultural use. The estimated average annual impact to the water supply is approximately 150,000 – 240,000 acre-feet or 15-19 %.

Who's Driving the Bus?

Global economic and societal trends that will impact the agricultural producing industry and influence production decisions in the next decade

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For many years, growers have believed that their destiny is solely in their own hands. Cropping decisions and agronomic practices were determined by the producer, usually in consultation with their marketers. Marketers responded to demand from the next level in the distribution chain, usually a broker or distributor of some manner. For many years there were many levels of decision making between the producer and the final consumer. Today's marketplace is dramatically different with a whole new set of players impacting the decision chain and changing the face of production agriculture. This paper will point out some of these changes and who is driving the new dynamics.

The information for the trends comes from the Food Foresight report compiled by Nuffer, Smith, Tucker Public Relations and is the collective wisdom of a panel of industry leaders and experts that meet annually to discuss the various trends in the food industry and analyze how the industry is responding to the changes over time. This report is used by many agriculture industry organizations for both short and long range planning. The interpretation of the trends is solely the opinions of this author.

Trend Number 1:

Retailers and Food Service Operators Drive Market Purchase Decisions in Response to Consumer Demands

Lifestyle issues are changing the needs of individuals.
Consumers are marshalling their own information sources.
Consumer-driven social networks build credibility.
In-store media helps with purchase decisions.

Trend Number 2:

The Food Pipeline is in Major Re-alignment

Large retailers are merging, then breaking up, then merging again.
Mergers have opened up new niche marketers.
Retailers are thinking strategically about their customer base.

Trend Number 3:

Food and Health Converge on Commercial Relevance

Health trends gain power with connection to genetics.
Research will soon pit commodities against each other.
Retailers bet on in-store health clinics.

Some commodities will fare better under this system than others.

Trend Number 4:

Sustainability Sows Seeds of Profit and Social Good

Consumers are increasingly considering a company's commitment to society.
Food safety heightens concerns.
Retailers' "carbon footprint " is taking a place in the consumers' decisions.
This trend is impacting mainly middle and high end markets but is showing signs of trickling down the line.

So how does all this vision from 30,000 feet impact the grower at ground level? Simply, it defines just who is driving the decision-making process and why there are so many new regulations and practices being developed to respond to the shift in issue management. In trend 1 we see how consumers are increasing their leverage with retailers and how retailers are working to be more responsive to the consumer requests and, sometime, demands. Trends 2, 3, and 4 also reflect this responsiveness to consumer input by providing additional services such as health care facilities within the marketplace and competing to be "more green than their competition". We see this mainly among the large retailers, but it is also driving a new emerging set of niche marketers competing at the high end of the spectrum for the elite dollars.

Focus on Food Safety:

The change in dynamics has caused retailers and foodservice operators to renew their outlook on a wide range of issues raised by their customers, and the most prominent area is in what is loosely known as "food safety". There are a number of factors involved in this debate that are relevant to this discussion. The primary factor is one of liability to the retailer or foodservice operator. The reasons for this are based on a constantly shifting attitude towards finding someone else to blame for an event in one's life. We seem to be a society that no longer can get a stomachache without finding someone else to blame. Also, we can argue until the beer runs out as to who is responsible for the problem, but there are several factors worthy of note that can be identified as discussion points.

The first factor is the emergence of law firms willing to file class action suits against anyone and everyone within a distribution chain when someone gets sick. A visit to the website of Marler Clark LLC in Seattle will give you a taste of the level of litigation in food borne Illnesses. They list 10 pages of events going back to 2005 where they have represented clients against large corporations and organizations. This has driven large and small retailers and food service operators to seek programs to shift the liability somewhere else. The result is a movement to define food safety programs to place the burden on the producers to ensure products are completely free of any pathogens or other contaminants that may cause illness at the consumer level.

The second factor driving the issue is the improvements among government agencies to track food borne illness events and trace pathogen pathways. USDA, FDA and the Centers for Disease

Control (CDC) have all improved the technology for detecting, identifying, and tracing illness related events to seek ways of blocking the pathways of outbreaks. The recent outbreak of *E.coli* in spinach is an example of just how specific this tracking system has become and how the industry was forced to respond as rapidly as possible. Even with the systems in place, there was significant economic loss to the producers while the tracing back system pinpointed the source. The fallout from this event is still a work in progress but has strengthened the resolve of both the distribution chain and the producers to improve and change the business practices in product handling.

A third factor is the susceptibility of consumers to opportunistic organizations and politicians to use the food safety issue as a platform to gain attention. Consumers will believe what they are told if it means shifting the responsibility from themselves to someone else for their own personal welfare. Following the spinach outbreak a number of legislative actions were proposed to " regulate" the industries and make the world a "safer place". This goes along with "I'm from the government and here to help!" mentality. Whether we agree with this philosophy or not, the facts are that we will face a whole new set of regulations in how we do business. These are a "work in progress" at this point and will be driven more by political motivations than scientific realities, so the challenge is out there to work within the system to keep some balance between the two.

So what does this all mean to us at the grower level?

First, we need to be aware of the factors driving change and understanding that we may not be in complete control of our destiny. Where this all originates is less important than recognizing that change will occur and that we need to be prepared to change with it. Consumer input will continue to drive the retailers and food service operators in their push for programs that will give them a leg up in the marketplace. Whether it be in the food safety arena or determining who has the smallest "carbon footprint" retailers will constantly seek competitive advantage.

Second, growers will need to keep an open mind as the new regulations and procedures roll out. A number of organizations are working within the distribution system to develop regulations that make sense to the producers while meeting the needs of the distributors. Such organizations as United Fresh, Produce Marketing Association and Canadian Produce Marketing Association are leading the efforts at the producer level. They are working with groups such as the Food Safety Leadership Council, a group of large retailers and food service organizations, the National Restaurant Association, and a group of food serves distributors who are all trying to develop their own set of standards. These organizations are trying to bring some level of consistency to the requirements and get the industry out of the "one up" position that many of the distributors are now doing. This is a work in progress and will probably take a year to sort out. In the meantime, we will all have to deal with the inconsistency within the distribution community. Many commodities are working on programs that will make sense for their individual practices and trying to get the point across that "one size fits all" is not a workable approach.

Finally, growers need to work with their industry organizations that are developing Good Agricultural Practices (GAP) programs and other practices to strengthen their positions with distributors who are demanding change. The drivers for all this change are many and carry a controlling voice in the debate. This is not to suggest that growers just roll over and accept the direction but that they become involved in shaping the change. If you are involved in a commodity that does not have a specific group working on this, at least follow what is being done by the overarching groups such as Western Growers, Ag Council, Farm Bureau, Grape and Tree Fruit League and Citrus Mutual. These all have working committees that are addressing the problem and trying to bring some sense of reality to the process.

You may not be able to drive, but get on the bus and have a great ride!!

Session I

Spray Technology

Session Chairs:

Ben Faber, UCCE, Ventura County

Dave Woodruff, Woodruff Ag Consulting

Plant Growth Hormones and the Use of Synthetic Growth Regulators in Horticultural Crops

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There are five major plant hormones in plants: 1) abscisic Acid, 2) auxins, 3) cytokinins, 4) ethylene, and 5) gibberellins. These hormones play important roles in all aspects of plant growth and development, including rooting, flowering, fruit set, growth differentiation, disease resistance, and adaptation to environmental stresses. The efficacy of hormones is influenced by hormone receptors, the concentration of one hormone relative to the other hormones, tissue type and the physiological stage of organ and plant development. In agricultural, there is a plethora of synthetic growth regulators used to regulate plant growth. In fruit and nut crops, growth regulators are used to promote fruit set, induce fruit drop, or induce fruit ripening. In many horticultural crops, growth regulators are used to induce flowering and control vegetative growth. The mode of action of endogenous hormones will be discussed. The types of synthetic hormones available and their proper use will then be discussed.

Uses of Plant Growth Regulators in Tree Nut Crops

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Introduction
The focus of plant growth regulator (PGR) use in tree nut crops is towards maximizing total yield and improving harvest efficiency more than increasing visual appeal. The effect of the PGR must be substantial in order to justify the development, registration, and application costs. This paper will briefly summarize PGR research known to the author in walnuts, almonds, pistachios, and pecans, and it will also identify some of the horticultural challenges faced in each of these crops that might be mitigated by PGR use.

Ethephon

Other than limited acreage in Oregon, California is the only state in North America where walnuts are commercially grown. Ethephon is used frequently as a preharvest aid in the southern growing regions where higher late summer temperatures delay walnut harvestability. Applied at packing tissue brown (the final stage of nut maturity where the tissue surrounding the kernel turns from white to a uniformly tan to brown color), ethephon provides exogenous ethylene to increase the rate of hull dehiscence. This greatly improves nut removal by mechanical shaking, accelerates harvest by seven to ten days, and improves nut quality from lighter colored kernels. Walnut meats darken naturally with age. This reduces consumer appeal and shortens their post harvest storage life limited by oxidation of the oils within the kernels. Ethephon application five to seven days post packing tissue brown improves nut removal over earlier treatment. The efficacy of ethephon on walnut is best under cooler temperatures (below 90° F). Higher humidity, especially predawn dews, also improves response presumably by increasing PGR absorption time. Research shows ethephon can increase walnut value by at least five cents per dry in-shell pound due principally to lighter kernel color and lower navel orangeworm damage...

Replicated tests on the walnut cultivars Serr, Payne, Tulare, and Chandler by the author indicate walnuts are not equally responsive to ethephon, a phenomenon which could be the more likely cause for poor commercial response in some cultivars, such as Serr, than inadequate coverage, high temperature, or incorrect timing. In 2007, the author dipped individual nuts (in vivo) of the above cultivars grown in the same location (Kearney Agricultural Center) in 600 and 1200 ppm ethephon solutions at packing tissue brown. Measurement of post harvest ethylene production 48 hours and four days after treatment via gas chromatography showed significant differences in the amount of endogenous ethylene produced between treated and untreated nuts, as well as between cultivars. Serr produced significantly less ethylene, regardless of the treatment concentration, than Payne, which developed PTB simultaneously with Serr and was treated on the same day. Ethylene production of untreated walnuts was similar among the four cultivars tested.

Research has also been conducted by the author to suggest that stress tolerant cultivars, such as Serr, resist defoliation from ethephon treatment, even when applied under low soil moisture conditions. A three-year trial compared Serr walnuts under well irrigated conditions to trees receiving 50% and 0% Etc 30 to 40 days prior to ethephon application at PTB. Predawn leaf water potentials showed significant differences in plant water status at the time of treatment.

Ethephon was applied at the commercial rate of four pints/ac in 200 gallons of water. A three-day delay in irrigation of all treatments was imposed following treatment to maximize stress. The trees where then rated for percent leaf drop prior to the first harvest 17 days after treatment. No differences in defoliation or percent removal on the first shake were recorded in any of the three years. Defoliation was less than one percent. Walnut growers claim heavy leaf drop in stressed Serr orchards. This difference may be due to season-long deficit irrigation compared to the experimental trees which were well-watered prior to their respective irrigation cut-offs. This research suggests Serr walnut growers could safely wait to apply ethephon at PTB without the risk of adverse defoliation from the resulting stress. Currently, growers forego treatment if PTB fails to coincide with irrigation requirements.

Severe defoliation results when ethephon is applied to pecan. This affects next year's buds. Tests in the mid-1970's on almonds showed no significant enhancement in hull split with ethephon. Application at this time delayed bloom four to five days the following spring. Pre-harvest treatments showed no improvement in nut removal, and sufficient gumming of spur wood prevented its registration.

Ethephon Inhibitors

Pistillate flower abortion (PFA) in walnut is the abscission of pistillate (female) flowers 2 to 3 weeks after bloom. It was first noted in the Serr cultivar shortly after the earliest plantings came into production in the 1970's. PFA affected Serr yields so severely in northern California that most growers removed or grafted orchards to cultivars not affected by this disorder. Serr orchards in the southern San Joaquin Valley of California were less affected by PFA and therefore remained an important cultivar because of its early maturity, high edible yield, and the role it plays in setting market conditions.

For over 30 years, the University of California Pomology Department (now Plant Sciences) at Davis (UCD), in cooperation with Cooperative Extension colleagues, researched the cause of PFA and its solution. Mites, walnut blight, numerous nutritional deficiencies (including nitrogen, calcium, and boron), tree age, shading, pruning practices, water stress, intra-tree competition, Cherry Leafroll virus (Blackline), incompatible pollen, and lack of pollination were all investigated and ruled out. In the 1980's, researchers in Hungary and UCD discovered that PFA is always associated with high numbers of pollen grains present on the receptors (stigmas) of the female flowers. In the 1990' s, Polito et.al., demonstrated PFA decreased and walnut yield increased with distance from a pollen source. Polito further reported that excessive pollen grains growing down the style of the flower produce high levels of ethylene, which most likely triggers flower abortion. His tests with reagent ethylene inhibitors supported this hypothesis.

The first field tests with the commercial product, ReTain®, an AVG-based ethylene inhibitor, were performed by the author in 2003. A four-fold increase in fruit set was observed over untreated flowers. In 2004, commercial speed sprayer trials performed in Kings and San Joaquin Counties at 25 and 50 grams ai/ac resulted in significant increases in percent set and yield improvements in excess of 1000 dry in-shell pounds per acre compared to untreated trees. Treatment was at an estimated 40% pistillate bloom. In 2005, trials performed in Kings and Tulare Counties examined the effects of application timings from prebloom to 70% bloom, as well as concentration (25 and 50 grams ai/ac) and water volume (100 and 200 gal/ac). The 2004 trial was also monitored for adverse carryover affects. The 20-30% and 60-70% bloom timings resulted in the greatest yield improvement (163 dry inshell lbs/tree) compared to untreated trees (76 lbs/tree). Half the recommended concentration (25 grams ai/ac) in 100 or 200 gal/ac provided a 30-lb/tree increase compared to. a 53-lb/tree increase with 50 grams ai/ac. No adverse carryover effect in the average two-year yield was observed in trees treated in 2004.

Continued research in 2006 and 2007 has provided similar yield increases with walnut varieties suffering from PFA. Yield increases are directly proportional to the number of female flowers present at the time of application and the severity of PFA. Research results indicate gains of 1000-2000 pounds of dry in-shell walnuts per acre are possible. ReTain® is **NOT** a general fruit set enhancer. Trees suffering from deficit irrigation, disease, nematodes, poor nutrition, or heavily shaded conditions will not benefit from ReTain® treatment. Thus far, Serr and Tulare are the two walnut cultivars showing the most benefit. Chandler has not shown improvement in the two replicated trials conducted in Kings County (Hanford, CA). This is not to say that Chandler, or other cultivars, will not benefit. The **KEY** to successful use of ReTain® is not the cultivar, but whether or not the orchard in question suffers from sufficient PFA!

Aerial applications were also tested in 2006 and 2007. Replicated trials indicate aerial treatment can equal the yield benefits from ground treatment, providing coverage is optimized, and the number of receptive flowers in the upper one-third of the canopy represents a large portion of the potential yield. High relative humidity may also significantly improve the response from aerial treatment by slowing the drying time and increasing absorption of the PGR. It has been hypothesized that the poor performance of aerial treatments performed under dry, warm conditions may be due to the ReTain® spray drying before it even hits the stigmatic surface of the female flower. This could greatly reduce absorption of the PGR. Aerial applications are typically made at about 20 gpa. For this reason, improved response may be achieved by applying 25 grams ai/ac in 20 gpa down the tree rows, then repeating this application rate across the tree rows. The value of doubling the application cost, while still only using 50 grams ai/ac, is dependent upon how severely depressed orchard yields are from PFA.

Promalin for Improved Branching

Walnuts are characterized as having poor branch angle and attachment of laterals arising from current season growth. This prevents growers from developing their primary scaffold branches in the same year as the trunk and thus, delays commercial harvest to the fifth or sixth year. In the mid-1980's, UC Davis researchers evaluated Promalin (BA plus GA_{4-7}) for its ability to increase lateral bud break. An unknown concentration was applied to buds in the dormant, slight green tip and 3-8mm growth stage. All Promalin treatments resulted in significantly fewer buds growing compared to untreated buds. Promalin treatment also caused significantly greater bud death. The most effective treatment for increasing lateral bud growth was cutting into the bark tissue directly above the dormant bud to the point that the blade reached the woody interior tissue, thus severing the phloem tissue and accumulating auxin in the bud. The benefits of this treatment have since been confirmed and it is now recommended to walnut growers during the first dormant pruning.

Rest Breaking Agents in Nut Crops

Pistachios have been shown to be responsive to the rest breaking agents hydrogen cyanamide (Dormex) and horticultural mineral oil, with the latter now widely used commercially due to cost and convenience. In addition to in-season use, oil is registered on pistachio for dormant control of soft scale and *Phytocoris(* a small plant bug which overwinters in the egg stage on one year-old wood and causes loss of young developing nuts by its feeding). In addition, dormant applied oil overcomes inadequate winter rest as a result of insufficient chilling hours. Field observation and chilling research suggests the primary California pistachio cultivars (Kerman female and Peters male) require approximately 800 hours below 45° F for normal leaf out and bloom development. A four-year research effort by the author tested the efficacy of oil applied in mid January, February, and March. The most consistent rest breaking occurred from oil treatment in mid-February. This timing also significantly increased split nut yield by an average of five pounds per tree. Harvest was also advanced by about four days. This timing was confirmed by a three-year commercial oil timing study in Madera County which examined weekly applications from January 17 to March 7. Weekly ratings of bud push and bloom confirmed that in the Madera area (one of the higher chilling pistachio regions), the best oil response (uniform and coincidental leaf out and bloom of male and female flowers) occurred from applications during the first two weeks in February. Treatment after mid-February was not as consistent or advanced. Waiting until mid-February also allows the maximum accumulation of "natural chilling" from winter temperatures below 45° F.

The horticultural mineral oils available for pistachio use vary widely in their characteristics. All are highly refined oils with high unsulfonated residue, and hence, very low risk of phytotoxicity. The most notable difference between oils is their "weight", which refers to the number of carbon atoms contained within the oil molecule. The significance of this to the agriculturalist is that oils made up of longer carbon chains ("heavy" oils) require more time to be metabolized by the plant tissue they come in contact with. Contrary to the opinion of some, oils do not simply "wear off" plant tissue. They are actually metabolized in the same manner as lotion applied to human skin. Researchers believe the extension of this residual improves the ability of oil to smother injurious insects, and rest breaking is enhanced by a longer period of elevated plant respiration. Prior to the days when longer carbon-chain oils were virtually free of impurities, this extended residual created great concern for injury to buds and young fruiting wood. The weight of modern oils is described by the temperature in ° F at which 50% of the oil "cracks" off from the refinery 's distillation tower. Obviously, oils cracking off the tower at higher temperatures have carbon-chains of higher molecular weight.

One of the first and most popular highly refined dormant oils was Volck®. Originally developed and marketed by Chevron Chemical, Volck® was the heaviest oil available, with a 50% distillation temperature of 476° F. This oil was well known for its rest breaking and insect management efficacy. Unfortunately, Volck® was discontinued in 2006 by its present owner. Volck has now been replaced with oils similar in their 50% distillation rating, but the carbon-based molecules comprising the oil have less range in molecular weight. This results in a slightly faster rate of breakdown on the plant tissue, which may affect their insecticidal and rest breaking efficacy. Britz Fertilizer is one company marketing a Volck®-like oil registered for pistachios. Its 50% distillation temperature is 470° F and I have confirmed its efficacy and safety on pistachio. Other oils researched and registered for pistachios include oils with 415 and 440° F 50% distillation temperatures. Oils "cracking" from the distillation refining tower at these lower temperatures are lighter in molecular weight. Lighter weight oils provide less risk of phytotoxicity.

My research with oil over ten years indicates pistachio is quite tolerant of dormant oil application. However, this is NOT to say oil damage cannot occur. I witnessed true oil burn for the first time on six-year-old trees in 2005 in Tulare County. It was isolated in one area of the block and the adjacent row showed no symptoms. The cause was never determined. The injury was limited to loss of vigorous, one-year-old wood in the tops of the canopies. Excessive vigor and low carbohydrates was suspected.

My research indicates oil with higher 50% distillation temperatures (470 oil) provides better rest breaking effects than lighter oils when the chilling hours are less than 700 hours. . Such a test was performed at Tejon Farming (base of the Tehachapi's) during the 2003 season where only 550 chilling hours were recorded. A 470 oil applied in mid-February resulted in 50% bloom on April 10 compared to May 1 for the untreated trees. Trees treated with a 415 oil were about five days behind those treated with 470 oil. Unfortunately, yield data collection was not possible.

I would treat mature trees in good chilling years only if early harvest was required to initiate processing.

Oil is not for everyone. It is a tool with many factors affecting its performance. It cannot put buds on trees! Nor can it overcome deficit irrigation, which significantly limits the tree's productive capacity from low carbohydrates and insufficient fruit wood. Oil applied at sprayer speeds too fast for optimal coverage, improperly timed, applied to stressed trees, used at too low a concentration, applied by tractor drivers who miss rows (a common occurrence), or used in an area with potential spring frost can easily negate any benefits of use.

Effect of PGRs on Alternate Bearing in Pistachio

Individual pistachio orchards can be very strongly alternate bearing, resulting in challenging budget issues for growers. Alternate bearing in pistachio is characterized by the production of abundant flower buds during the heavy bearing year which then abscise from the tree during August when the tree is under heavy demand for growth substances to complete kernel filling. Attempts to resolve this issue through the use of PGRs began in 1972 by Dr. Julian Crane, UC Davis Pomology Department. He tested single foliar sprays of PCPA (auxin) in late June, just prior to the initiation of kernel filling. He also tested single applications of benzyladenine(6-BA, a cytokinin) in June. Both tests delayed, but failed to prevent flower bud loss. It was later hypothesized by Dr. Louise Ferguson, UC Davis Plant Sciences, that the lack of response was possibly due to insufficiently sustained PGR concentration. Consequently, in 1986 she tested silver thiosulfate (ethylene inhibitor) at various concentrations against defruited shoots just prior to the beginning of kernel filling (July 2). She also tested 100 ppm PCPA (auxin), 20 ppm 2,4-D, and 50 ppm 6-BA alone and in combination with GA_{4-7}. Each treatment was applied three times (June 25, July 25, and August 25). The results showed that auxin and 2,4-D both significantly increased fruit bud retention compared to untreated fruiting and non-fruiting controls. The lack of response from silver thiosulfate indicated ethylene was not a factor in fruit bud abscission.

This lead to the extensive research efforts of Dr. Carol Lovatt, UC Riverside, who performed a series of in-depth field experiments to elucidate the role and concentration of PGRs in pistachio fruit bud retention. In simple terms, she discovered that abscisic acid increased in the fruit buds, with a corresponding decrease in the neighboring fruit. The cytokinin concentration also fell in the fruit buds during kernel filling. Subsequent tests with foliar applied cytokinins in the form of 6 benzyladenine combined with low biuret urea (facilitating PGR uptake) increased flower bud retention significantly. Further field tests on whole trees showed a 43% increase in fruit bud retention with June and July applications of 6 BA+urea during the on-crop year. Pistachio trees treated annually for five years yielded 37.4 pounds more dry split nuts than the untreated controls. Lovatt's research lead to the development of a cost effective 6-BA based product called MaxCel (Valent BioSciences), which is now registered for use on pistachios for mitigating alternate bearing.

Other PGR Efforts

Attempts to improve almond nut removal, advance maturity, and achieve better cross-pollination between cultivars with Alar, ethephon, and Cycocel had some success but the side effects of smaller kernel size and phytotoxicity stopped further investigation in the 1970's. The author is unaware of any research with PGR's to control tree size once full canopy is attained.

Summary

This paper is by no means an exhaustive review of past and recent efforts to employ PGRs to the benefit of nut crop production. It does provide a description of several successful and commercially useful PGR programs that the reader may wish to pursue. Additional screening of PGR effects in nut crops is needed to solve problems associated with uniform harvest, canopy size control, shell splitting, and reduced forces for nut removal.

Spray Technology

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Western Farm Service is a major supplier of application services to California agriculture, with annual pesticide applications of 500,000 acres. For the last three years WFS agronomist have conducted trials to improve the efficacy and efficiency of pesticide applications, while reducing drift and maintaining applicator safety. Too facilitate this research WFS constructed separate spray units for row crops and trees and vines. Elements of application evaluated included nozzle selection, nozzle alignment, spray volumes, spray pressure, ground speed and adjuvant chemistry.

Observations of current pesticide application technology
Application technology has advanced little in the last 50 years. Tractor comfort and worker protection are the only significant areas of implemented change, with the exception of flow control systems. Nozzle selection, spray volumes, ground speed and spray deposition are in many cases basically unchanged from a half century ago.

Conclusions from three years of row crop trials
High gallonage and good coverage are not necessarily synonymous
Twin Cap nozzle bodies with low drift nozzles can provide good coverage while reducing drift
Adjuvants are essential for good coverage

Conclusions from two years of Tree and Vine Trials
High gallonage and good coverage are not necessarily synonymous
Low drift nozzles can provide good coverage
New fan technology can provide good coverage while reducing the potential for drift
Adjuvants are essential for good coverage

Future trials will incorporate optical technology and environmental monitoring systems.

Zinc Movement and Distribution within a Peach Tree

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Zinc (Zn) deficiency is commonly observed in California peach trees, particularly when grown on Nemaguard rootstock. Foliar sprays are generally applied yearly to alleviate the problem or, in many cases, to prevent the problem from occurring. Some of these applications are probably unnecessary. In addition, zinc is not taken up very efficiently into plants, so relatively high rates of different formulations are applied in order to supply a small amount to the trees. One of the objectives of our research has been to improve both the sampling and application procedures for zinc with the goal of eliminating unneeded sprays and/or reducing the amount of material applied. A more thorough understanding of the movement and distribution of zinc within a peach tree should provide clues and suggest strategies for achieving this goal.

Zinc Distribution within a Peach Tree

Zinc within the fruiting shoots of a dormant peach tree shows a very uneven distribution throughout the plant with much higher concentrations in the lower part of the canopy (Table 1). Exposure to sun appears to be a factor as well. Shoots on the inside of the canopy have higher concentrations than those in outer, more exposed locations at the same height. Thus, shoots in the lower interior portion of the canopy can have almost 5 times greater zinc concentration than those in full sun at the top of the trees. This gradient quickly disappears the next spring as new growth pushes out (Table 1). Thus, the gradient is likely created during summer and/or fall as nutrients are translocated towards the roots for storage. Recent research has demonstrated that foliar zinc moves readily into the roots of a peach tree (Sanchez et al., 2006), which may not be the case for other fruit and nut crops (Swietlik, 1999).

As peach shoots grow in length during the spring, a Zn gradient is established in the leaves along the shoot. However, the direction of the gradient depends on the tree's Zn status. Deficient trees have proportionately more Zn near the tip while the opposite is true for high Zn trees (Figure 1). Typical commercial peach orchards, which generally fall somewhere between these two extremes (termed Zn sufficient), show no gradient at all. This information reinforces the conclusion that Zn moves readily in peach trees, especially deficient ones. It also suggests that basal leaves of young developing shoots could be a good indicator of tree Zn status - deficient trees have depleted levels and high Zn trees have enhanced levels.

The pattern of leaf Zn throughout the season adds further evidence for these conclusions and raises questions about the usefulness of mid season leaf Zn values. In deficient trees there is an initial peak of Zn as growth starts, but then the values quickly drop to about 10 ppm and remain there or slightly lower for the rest of the season (Figure 2). High Zn trees maintain leaf levels above 40 ppm until final leaf senescence. Once again, the average commercial orchard (Zn sufficient) has an intermediate pattern. It tends to drop off steadily throughout the whole season. By late summer and early fall, its leaf Zn level is not too different from the deficient trees. Thus, a mid summer leaf sample would not be as accurate as an early spring sample for separating Zn sufficient trees from deficient ones. Some have reported that the standard mid summer leaf sample is not very accurate for determining tree Zn status (Sanchez and Righetti, 2002).

We have proposed an alternate approach to sampling that appears to have great promise for Zn (Johnson et al., 2006). It involves sampling fruiting shoots during the dormant season. When combined with the information on Zn distribution throughout the tree discussed above, we have obtained results showing very substantial differences in lower, shaded shoots among trees of different Zn status (Table 2). Just recently, we further tested an earlier timing of early September and obtained similar results. Finally, root Zn also showed similar differences among treatments. Thus, there are several tissues and timings that could be useful as a sampling tool.

Implications for Nutrient Sampling

This detailed analysis of Zn distribution suggests certain times may improve our ability to determine the true Zn status of the tree. Distinguishing high Zn status from deficiency can easily be accomplished at any sampling period. However, separating typical commercial orchards (sufficient Zn) from deficient ones is more of a challenge. Using leaf samples, it appears the further into the season, the less separation can be expected (Figure 2). Thus, an early spring sample would be best, especially if basal leaves are analyzed (Figure 1). One problem with this procedure is that rapid changes are occurring at this time, which could make it difficult to establish a reliable standard.

Sampling dormant shoots, especially in the lower part of the canopy, could also be a useful tool for distinguishing between sufficient and deficient trees (Table 2). In orchards where foliar summer or fall Zn treatments have been made, this procedure would generally not work as it is very difficult to wash Zn materials off the surfaces of leaves and shoots. In these situations, root samples could be taken, even though it takes a little more effort. Finally, there appears to be promise in an earlier shoot sampling procedure that could fit well into a fall Zn treatment program. These approaches still need to be more widely tested in commercial orchards.

Implications for Zinc Treatments

In commercial (Zn sufficient) orchards, Zn appears to steadily decline in mature leaves throughout the season (Figure 2). This is in contrast to nitrogen which stays fairly constant in the leaves until senescence in the fall. The continual drop in Zn suggests it is constantly being exported out of the leaf (and perhaps into storage in the shoots and roots). Thus, one approach to supplying the tree with Zn might be to tie into this steady export by providing small amounts throughout the season. This could be expensive as it would require multiple applications, but might be the most effective method.

Another approach might be to take advantage of the remobilization of Zn that takes place during leaf senescence in late fall, although this seems to only occur in high Zn trees (Figure 2). Thus, it may be necessary to have an abundance of leaf Zn in order for this to occur. This suggests an approach of loading up the leaves with Zn during early fall so it is available for remobilization during senescence. In some plants it has been suggested that the movement of certain nutrients like Cu and Zn are closely tied to the remobilization of N (Hill et al., 1979). Field trials with different rates and timings are needed to test these strategies of supplying zinc to a peach tree.

Literature Cited

Hill, J., A. D. Robson, J. F. Loneragan. 1979. The effect of copper supply on the senescence and the retranslocation of nutrients of the oldest leaf of wheat. Annals of Botany, 44:279-287.

Johnson, R. S., H. Andris, K. Day, and R. Beede. 2006. Using dormant shoots to determine the nutritional status of peach trees IN: Proceedings of the 5th International Society on Mineral Nutrition of Fruit Plants (Retamales, J.B., and G. A. Lobos, eds.). Acta Horticulturae 721:285-290.

Sanchez, E. E. and T. L. Righetti. 2002. Misleading zinc deficiency diagnoses in pome fruit and inappropriate use of foliar zinc sprays. Acta Horticulturae 594:363-368.

Sanchez, E. E., S. A. Weinbaum, and R. S. Johnson. 2006. Comparative movement of labeled nitrogen and zinc in 1-year-old peach [*Prunus persica* (L.) Batsch] trees following late-season foliar application. Journal of Horticultural Science and Biotechnology 81(5):839-844.

Swietlik, D. 1999. Zinc nutrition in horticultural crops. Horticultural Reviews, 23:109-178.

Table 1. Zinc distribution throughout a Grand Pearl nectarine tree at different times of the season.

Date	Location						
	Low Shaded	Low Exposed	Low Water sprouts	Mid Shaded	Mid Exposed	High Exposed	High Water sprouts
12/21/05 (shoots)	70.3 a*	39.7 bc	32.6 cd	47.9 b	28.5 de	19.1 d	16.3 f
	Low			Mid		High	
4/21/06 (leaves)	52.6 a			47.6 b		44.3 b	
5/23/06 (leaves)	38.9 a			38.2 a		36.1 a	
7/6/06 (leaves)	20.6 a			21.4 a		19.9 a	

*Values in a row followed by the same letter are not significantly different at p=0.05 by Duncan's Multiple Range Test.

Table 2. Zn content of shoot or root samples from Grand Pearl nectarine trees of deficient, sufficient or high Zn status.

		Zn status		
Date	Tree location	Deficient	Sufficient	High
December 2006	Low shoots	10.1 c*	35.6 b	74.5 a
December 2006	Mid shoots	8.1 c	21.6 b	50.0 a
December 2006	High shoots	6.4 c	13.7 b	26.5 a
December 2006	Roots	6.6 c	24.3 b	62.5 a
September 2007	Low shoots	6.4 c	26.0 b	92.0 a

*Values in a row followed by the same letter are not significantly different at p=0.05 by Duncan's Multiple Range Test.

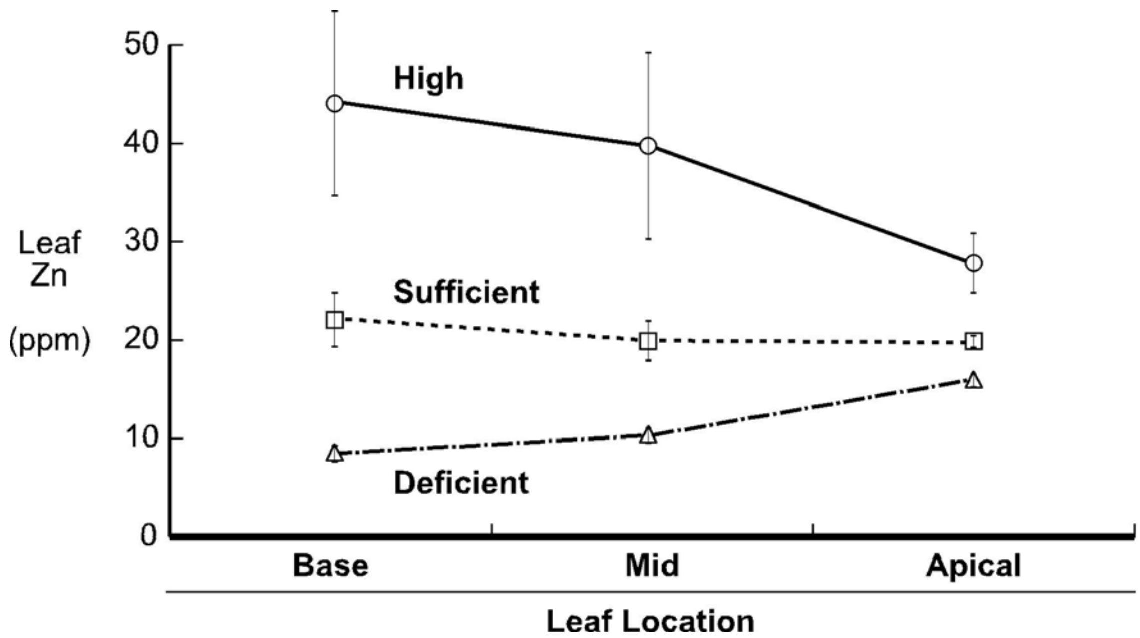

Figure 1. The distribution of Zn among leaves sampled from different locations on growing shoots of Grand Pearl nectarine in June, 2006. Six or seven trees were classified as Deficient, Sufficient or High based on deficiency symptoms and Zn fertilization rates.

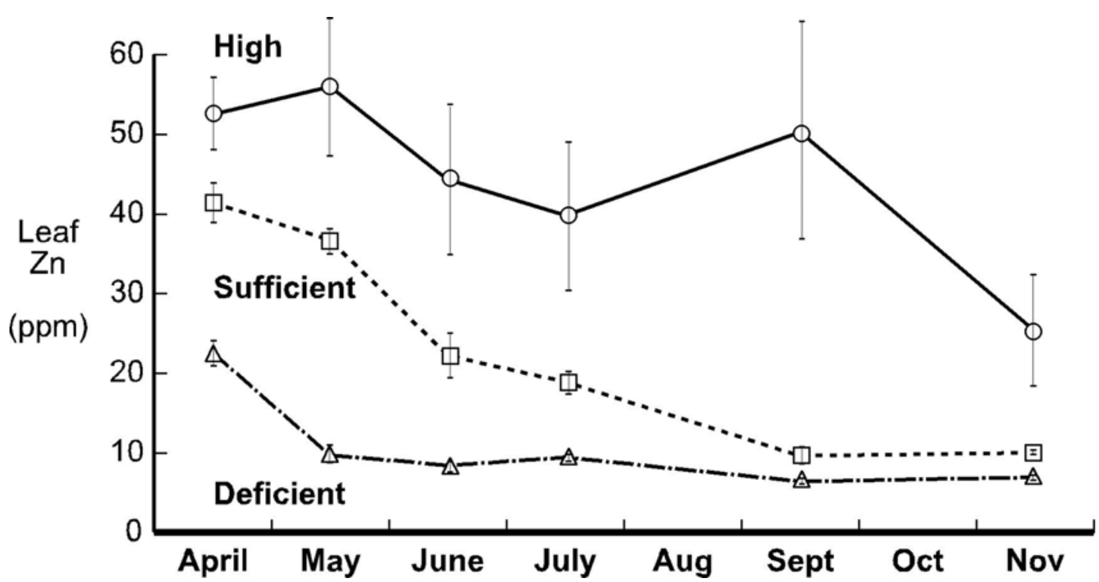

Figure 1. The Zn content of Grand Pearl nectarine leaves sampled throughout the 2006 season. Six or seven trees were classified as Deficient, Sufficient or High based on deficiency symptoms and Zn fertilization rates. The November sample was senescing leaves.

Considerations In Effective Spray Coverage

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Effective control of Red Scale with spray materials requires successful completion of several steps. If any one of these is lacking the effectiveness of the spray will be limited. Most people involved with red scale appreciate the fact that a spray treatment is expensive, however not all appreciate the difficulty of achieving adequate coverage of the spray material. There are three key ingredients in any effective red scale spray-timing, material and coverage. Assuming that the timing of the spray and choice of an effective material are adequate, then coverage remains to be successfully completed as retired researcher Dr. Glenn Carman once stated "It doesn't matter what you miss them with". Effective spray coverage is itself made up of several critical consideration-natures of the pest, tree canopy, and equipment characteristics and set up, and equipment operation. Another critical component of an effective spray is evaluation-how do you know if the spray is going where you want?

California Red Scale infests all portions of a citrus tree-fruit, wood and leaves. In addition, the young scale after emerging from the adult female settle a short distance away and remain stationary the rest of their life (except the adult male which at maturity emerges as a winged form for 48 hours and then dies). Red scale therefore is distributed throughout the tree and is stationary; this means a spray must be thoroughly distributed to all of the surfaces of the tree.

The type of coverage required if a scale spray is also related to type of material used, that is, is the material oil or non-oil material. Oils act on scale insects by suffocation; the material must cover the insect's body to accomplish this, therefore a film wetting of all plant surfaces is required. Non-oil materials interfere chemically with the scale physiology requiring the spray material to contact the insect; this requires a tight stipple pattern, only slightly less demanding than a film wetting. Three non-oil materials have been available for re scale sprays for a number of years. This year two additional materials referred to as insect growth regulators received emergency registration. These growth regulators inhibit the formation of chitin and the armor covering of the insect. Contact by spray droplets or by crawlers moving through the spray residue is necessary for these materials to be effective. With these materials as with the three previously registered scale materials, thorough coverage of all canopy surfaces is necessary.

An equally critical area in spray coverage is the spray equipment. In general, two types of equipment are used in red scale sprays, the oscillating boom and the air-blast units. Boom equipment relies on hydraulic pressure to propel spray droplets into the canopy while the air carrier units use high volumes of air at moderate to high velocity to carry and distribute spray droplets. While use of the boom for red scale sprays requires high gallonage applications, air carrier equipment is available for concentrate (100 gallons per acre) or high volume dilute sprays (750-2000 gpa). With either the boom or air carrier machines the objective of the spray remains the same, thorough coverage of the tree canopy. If that is not accomplished, the treatment will be less than fully effective. To be effective the sprayer must be capable of moving the spray droplets into and through the wall of leaves, fruit and branches and deposit the droplets in tight stipple pattern on all plant surfaces. This requires driving the droplets either by hydraulic pressure or air velocity to their target. As the droplets move from the discharge point of the sprayer and travel through the canopy wall, they loose momentum and reaching the most difficult surface, the top center of the tree, becomes increasingly difficult. In light of this, it is no wonder that the most common area for scale survival following a spray is the top center of the tree. Historically, low silhouette air carrier machines where spray is discharged from a point close to the ground have had difficulty in achieving thorough coverage in this area of the tree. Discharge of the spray from a point further from the ground, as from a tower mounted on the sprayer, has facilitated coverage in this area.

Spray discharge from a sprayer is made up of a range of droplet sizes. Average size and range in size depends upon the equipment. Average size in dilute, high volume sprays (1000-1500 gpa) is typically larger than that in a concentrate spray (100 gpa). In dilute sprays the range might be 100-600 microns median volume diameter while in the concentrate spray the range might be 50-150 microns median volume diameter. Concentrate spray equipment develop a very high number of small droplets compared to the much smaller number of considerably larger drops from dilute equipment. Droplet size is a significant factor in spray coverage. Regulation of droplet size is achieved by pressured nozzles, droplets entrained in high volume air streams, or high velocity air moving across low pressure shearing nozzles. In conjunction with droplet size is the corresponding issue of propelling the droplet to the target. With oscillating booms it is a high volume of water under high pressure (450-550) psi that carries the spray. With air carrier equipment, large fans capable of moving high volumes of air or moderate volumes at high speed carry the droplets into the canopy. The goal then, is to develop adequate droplet size and adequate pressure behind the spray or sufficient volume or velocity of air to act as the vehicle to distribute the spray throughout the canopy.

Oscillating booms are equipped with a series of nozzles on a vertical shaft which oscillates in a figure-eight pattern-the speed of oscillation being adjustable. The spray stream from the nozzles should be adjustable so that the correct cone of the spray is achieved to adequately penetrate the canopy. Pump capacity must be able to maintain spray pressure between 450-550 psi. Height of the top spray gun (nozzle) must be as high as the top of the tree to allow the stream to spray directly into the top portion of the tree. Ground speed is critical and should be in the range of 1.25-1.50 mph. Nozzle size selection is critical with larger sizes necessary toward the top of the boom to achieve coverage in the top of the tree, the most distant from the point of nozzle discharge.

Nozzling in air carrier equipment typically is either a series of hollow cone nozzles with discs and swirl plates at the tip or shearing type nozzles. Droplet size is regulated in hollow cone nozzles by the size of the discs and swirl plate and the pressure behind the nozzle and in addition the volume of air into which the droplet is discharged. Shearing nozzles discharge the spray from minimally pressurized nozzles with high velocity air moving across the nozzles. Nozzle set up (size selection and location) is critical in equipment set up because size of droplets and volume of water being discharged from different points in the sprayer determines in large part how well the various portions of the canopy will be covered. The historical recommendation has been that 2/3 of the spray volume should be directed at the top ½ of the tree to obtain thorough distribution of the spray. With hollow cone nozzles this requires appropriate selection and location of discs and swirl plates in respective portions of the discharge area. With shearing nozzles adjustment of selection levers must be made to accomplish similar delivery of spray volume to the upper portion of the canopy. After repeated use nozzles become worn; droplet size and volume discharged is changed-this is critical. Worn nozzles should be replaced. Incorrect nozzling initially, or worn nozzles will result in inadequate coverage and inadequate control.

The speed of the equipment as it moves from tree to tree significantly affects coverage. Excessive speed does not allow sufficient time for the sprayer to remain opposite the tree long enough to discharge the spray for thorough coverage, while excessively slow forward movement results in over-spray. Optimal ground speed for boom and air blast equipment is 1.4-1.5 mph. Excessive ground speed is generally considered to be a major weak point in effective coverage. Operating equipment at that speed is taxing to the driver but it is critical if thorough coverage is the object of the operation.

Set-up of the equipment must match the tree target. Citrus trees vary significantly as to height, width and density, therefore using the same set up from on block of trees to another without seriously considering the canopy characteristics is risking inadequate coverage and inadequate control and less than anticipated results from an expensive operation. Measurement of tree canopies in a number of locations in recent years confirmed that canopy configurations differ as to location of maximum density which would influence equipment capability of effectively penetrating and depositing spray material. Very large canopies present challenges to effective deposition of spray whether the canopy is excessively wide or tall-in both cases droplets must travel additional and, or interference by foliage that has to be penetrated results in an inadequate number of drops for coverage on the target surface- "it doesn't matter what you miss them with".

Watching a dilute spray operation for red scale is impressive with the feeling that all of the tree must be wet with spray. But quite often, on closer inspection, dry spots are found and you are only able to really inspect the lower 6-7 feet from the ground-what the upper 5-10 feet which are even further from the nozzles? If you are checking coverage and there has been only water in the tank, you can climb in a few trees and evaluate coverage. Another method, is to place dye in the water, then position water-sensitive paper at various points in the canopy that will show spray deposits. Lack of a thorough stipple pattern in all parts of the tree translates into inadequate coverage, missing scale and inadequate control. When spray-card pattern is not a tight stipple pattern (adjacent droplets), then a review of set-up and operation must be done. Where is the coverage incomplete-lower ½ of the tree, top ½, interior of the canopy wall? Is the nozzle size selection and location adequate? Is it adjusted properly? The more dense foliage and the more distant surfaces will require larger nozzles to penetrate and, or, travel greater distances. With shearing nozzles volume selection at the spray manifold should take this into consideration. Ground speed of the equipment must be verified. At 1 mph the equipment will travel 88 feet in one minute; this can be time after a distance is marked off or a number of tree spaces are marked. With pressurized nozzles recommended pressure should be confirmed at the manufacturers recommend RPM's. If volume output is not as expected, nozzle size should be confirmed, nozzles parts checked for wear. The coverage test should then be repeated. "This is tedious and unnecessary you may hear", however, too many sprays look good but are leaving dry areas in the canopy.

Achieving control over scale infested fruit is very difficult and surviving scale reinfests the canopy. Harvesting the fruit before spraying and not leaving fruit after picking increases the effectiveness of the spray.

Good procedure is a must if good coverage is the goal. Good coverage is a must if good scale control is the object of the spray. Make sure the equipment is doing the job. Proper set-up to match the canopy. Good operating procedure. Evaluate the coverage before you begin. “It doesn’t matter what you miss them with”.

e/mary/Neil/Spray CA Red Scale

Session II

Water Supply/Irrigation/Water Quality

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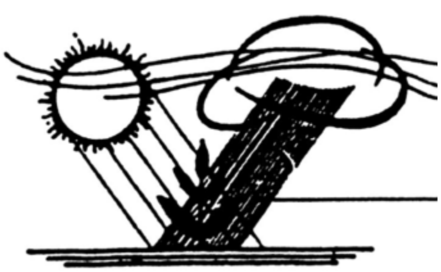

Spatial and Temporal Trends in Nitrate Concentration In the Eastern San Joaquin Valley Regional Aquifer and Implications for Nitrogen Fertilizer Management

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Introduction

Ground-water withdrawals in the San Joaquin Valley totaled 64 million m^3/day (19 million ac-ft) in 2000, supplying about 45% of agricultural irrigation demand and about 80% of municipal supply (Hutson et al., 2004). Most of the population and ground-water use are in the eastern San Joaquin Valley, where reliance on ground water is expected to increase as a result of rapid population growth and limited surface water supplies. Protection of ground-water quality for future use requires monitoring and understanding the mechanisms controlling the long-term quality of ground water in the regional aquifer system.

Nitrate has been widely detected above background concentrations in ground water in the eastern San Joaquin Valley. Nitrate concentrations (reported as nitrogen in this paper) were above the MCL of 10 mg/L in 24% of domestic wells screened in the shallow part of the aquifer that were sampled during 1993–95 (Dubrovsky et al., 1998) and the Central Valley is one of the top three regions in the state in terms of the number of public drinking-water wells exceeding the MCL for nitrate (California State Water Resources Control Board, 2002).

To assess spatial and temporal trends in nitrate concentrations in the eastern San Joaquin Valley and to evaluate the long-term effects of nitrogen fertilizer use on ground-water quality in this region, data were evaluated at multiple spatial scales. Data from regional-scale monitoring networks were used to map the regional occurrence of nitrate and to determine whether shallow ground water containing elevated nitrate is migrating to deeper parts of the aquifer system. At the local scale, mean ground-water ages from analysis of age-dating tracers were combined with concentrations of nitrate to reconstruct nitrate inputs in recharge through time and to compare with estimated nitrogen applications. Ground-water flow and transport simulations of a typical public-supply well screened from about 100 to 400 ft below the water table were used to evaluate long-term concentrations beneath agricultural areas under different nitrogen management scenarios.

Occurrence of nitrate in the regional aquifer

Regional spatial and temporal trends in nitrate during the last two decades vary according to the position of the sampled wells in the regional ground-water flow system. Nitrate concentrations are highest and most variable near the water table, and variability and concentration decrease with depth (Burow et al., 2007) (fig. 1). In areal networks of monitoring wells screened near the water table in agricultural areas, nitrate concentrations in the 2000s ranged from 0.04 to 34 mg/L, with a median of 16 mg/L (Burow et al., in press). Nitrate concentrations were greater than the MCL in 67% of the wells. Nitrate concentrations in the

2000s in the shallow part of the aquifer system at depths of domestic wells (fig. 1) ranged from <0.05 to 75 mg/L, with a median of 6.4 mg/L. Nitrate concentrations were greater than the MCL in 29% of sampled domestic wells, indicating that domestic drinking-water supplies have been significantly affected by nitrate concentrations. In the 2000s, nitrate concentrations deeper in the aquifer, where public-supply wells are typically screened, ranged from 0.5 to 9.9 mg/L, with a median of 3.7 mg/L.

The largest increases in nitrate concentrations during the last decade were in the shallowest wells; the median increase in nitrate concentration decreased with depth (Burow et al., in press) (fig. 1). In the monitoring wells screened near the water table in agricultural areas, median nitrate concentrations increased from 11 to 14 mg/L in oxic wells during the last decade, although the increase was not statistically significant. In the shallow part of the aquifer system at depths of the domestic wells, median nitrate concentrations increased significantly from 6.1 to 7.3 mg/L in oxic wells during the last decade. In the deep part of the aquifer where public-supply wells are screened the median nitrate concentration increased significantly from 3.4 to 3.7 mg/L during the last decade. A large database of historical nitrate concentration data from wells in the shallow and deep parts of the aquifer was constructed to evaluate long-term changes in nitrate concentrations (Burow et al., in press). These data also show that nitrate concentrations have increased over the last several decades in both the shallow and deep parts of the aquifer, with concentrations increasing more gradually at depth. In view of the widespread occurrence of nitrate concentrations over the MCL in the shallow part of the aquifer and increasing concentrations with depth, a quantitative evaluation of the decadal-scale fate and transport of nitrate in the eastern San Joaquin Valley is needed to design mitigation strategies for the high concentrations in the shallow part of the aquifer and to protect future water supplies tapping the deep part of the aquifer.

Sources of nitrate

The observed decrease in nitrate concentrations with depth is consistent with an increase in nitrogen fertilizer applications over time. Initial nitrate concentrations in recharge and corresponding nitrogen fertilizer applications increased over time in three separate local-scale studies near 1) Fresno (fig. 2a) (Burow et al., 2007), 2) Modesto (fig. 2b) (Burow et al., in press), and the Merced River (fig. 2c) (Green et al., in press(a)). Manure applications were included in the nitrogen input curve for the site near the Merced River because of nearby confined animal operations. Analysis using county-level nitrogen applications and a wide range of chemical data from sampling vertical monitoring well transects showed that reconstructed nitrate concentrations are consistent with 50% of the applied nitrogen reaching the water table. Similar temporal trends and leaching fractions (typically 30 to 50%) have been reported for agricultural recharge in other areas in the United States (Böhlke and Denver, 1995; Böhlke, 2002; McMahon et al., 2006). Nitrogen application data (Ruddy et al., 2006) and isotopic data from the local-scale studies (Green et al., in press(b); McMahon et al., in press) indicate that nitrogen fertilizer is the dominant source of nitrate in modern ground water, although locally in areas with confined animal operations, manure inputs (Ruddy et al., 2006) could increase expected nitrate concentrations in recharge by as much as 38 to 66%. Septic inputs of nitrogen to ground water can be locally significant; however, septic density is sparse in comparison to the area of fertilized crops in the study area. Atmospheric deposition of nitrogen is low.

Persistence of nitrate and mixing processes in the regional aquifer

Physical processes such as dispersion and mixing affect nitrate concentrations as nitrate moves deeper in the ground-water system. In deep, long-screened wells, low nitrate concentrations may be caused by the increased mixtures of ages of ground water with depth (Weissmann et al., 2002). In these wells, young, high-nitrate ground water is mixed with older, low-nitrate ground water, resulting in low observed nitrate concentrations. As the proportion of young, high-nitrate ground water increases in the deep part of the aquifer, concentrations of nitrate are expected to increase.

Microbial reduction can remove nitrate in geochemically reduced environments with sufficient organic content. Concentrations of nitrate in the regional aquifer are expected to generally persist over time because the aquifer sediments have low organic content and ground water is typically oxic (Burow et al., 1998; Burow et al., 2007; Jurgens et al., unpublished data, 2007). In the aquifer beneath Modesto, excess N_2 concentrations systematically increased with depth at multiple well nests, implying that small amounts of denitrification occurred in the aquifer even though it was generally oxic (McMahon et al., in press). Denitrification has also been reported in ground water in the vicinity of the Merced River (Domagalski et al., in press; Green et al., in press(b)). At that site, denitrification accounted for removal of as much as 50% of the nitrate in 31 years of reaction time.

Implications for management of nitrogen inputs

Based on estimates of ground-water age in the deep part of the aquifer, current concentrations of nitrate in public-supply wells likely reflect the fertilizer application rate and management practices of 40 to 50 years ago mixed with older waters prior to significant fertilizer use (Burow et al., in press). Therefore, concentrations of nitrate will likely increase as the proportion of young water contributed to these wells increases with time. Simulations using a detailed flow and transport model of a typical public-supply well indicate that for current nitrate input concentrations at the water table in agricultural areas of 15 mg/L, nitrate concentrations across the range of about 100 to 400 ft below the water table in the aquifer would approach the MCL of 10 mg/L within the next several decades (fig. 3).

Because geochemical reactions do not significantly affect nitrate concentrations between the root zone and the water table, controlling high nitrate concentrations in shallow ground water is dependent on physical factors, such as nitrogen fertilizer applications and recharge rates (Green et al., in press(a)). For example, increased fertilizer efficiency, resulting in the reduction of nitrogen inputs at the water table from current levels by 33% over 20 years could reduce nitrate concentrations sufficiently to maintain concentrations below the MCL (fig. 3). However, nitrate concentrations will continue to increase for 20 years after the reduction in input because of the lag time between the change in management and response in the deep aquifer. Whether or not measures are adopted to decrease nitrogen inputs at the water table, continued monitoring of nitrate concentrations in the regional aquifer at multiple scales provides the data necessary to assess management alternatives and to address the efficacy of measures adopted in the future.

Literature Cited

Böhlke, J.K., 2002, Groundwater recharge and agricultural contamination: Hydrogeology Journal, v. 10, pp. 153–179.

Böhlke, J.K, and Denver, J.M., 1995, Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland: Water Resources Research, v. 31, pp. 2319–2339.

Burow, K.R., Dubrovsky, N.M., and Shelton, J.L., 2007, Temporal trends in concentrations of DBCP and nitrate in ground water in the eastern San Joaquin Valley, California, USA: Hydrogeology Journal, v. 15, pp. 991–1007. Available at http://dx.doi.org/10.1007/s10040-006-0148-7

Burow, K.R., Shelton, J.L., and Dubrovsky, N.M., 1998, Occurrence of nitrate and pesticides in ground water beneath three agricultural land-use settings in the eastern San Joaquin Valley, California: U.S. Geological Survey Water-Resources Investigations Report 97-4284, 51 p.

Burow, K.R., Shelton, J.L., and Dubrovsky, N.M., in press, Regional nitrate and pesticide trends in ground water in the eastern San Joaquin Valley, California: Journal of Environmental Quality, v. 37, doi:10.2134/jeq2007.0061

California State Water Resources Control Board, 2002, Nitrate/nitrite groundwater information sheet. Available at http://www.waterboards.ca.gov/gama/docs/nitrate_oct2002_rev3.pdf

Domagalski, J., Phillips, S., Bayless, R., Zamora, C., Kendall, C, Wildman, R., and Hering, J., in press, Influences of the unsaturated, saturated, and riparian zones on the transport of nitrate near the Merced River, California, USA: Hydrogeology Journal

Dubrovsky, N.M., Kratzer, C.R, Brown, L.R., Gronberg, J.M., and Burow, K.R., 1998, Water quality in the San Joaquin-Tulare Basins, California, 1992–95. U.S. Geological Survey Circular 1159.

Green, C.T., Fisher, L.H., and Bekins, B.A., in press(a), Nitrogen fluxes through unsaturated zones in five agricultural settings across the United States: Journal of Environmental Quality, doi:10.2134/jeq2007.0010

Green, C.T., Puckett, L.J., Böhlke, J.K., Bekins, B.A., Phillips, S.P., Kauffman, L.J., Denver, J.M., and Johnson, H.M., in press(b), Limited occurrence of denitrification in four shallow aquifers in agricultural areas of the United States: Journal of Environmental Quality, doi:10.2134/jeq2006.0419

Hutson, S.S., Barber, N.L, Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268

McMahon, P.B., Böhlke, J.K., Kauffman, L.J., Kipp, K.L., Landon, M.K., Crandall, C.A., Burow, K.R., and Brown, C.J., in press, Source and transport controls on the movement of nitrate to public supply wells in selected principal aquifers of the United States: Water Resources Research.

McMahon, P. B., K. F. Dennehy, B. W. Bruce, J. K. Böhlke, R. L. Michel, J. J. Gurdak, and D. B. Hurlbut, 2006, Storage and transit time of chemicals in thick unsaturated zones under rangeland and irrigated cropland, High Plains, United States, Water Resources Research, v. 42, W03413, doi:10.1029/2005WR004417.

Ruddy, B.C., Lorenz, D.L., and Mueller, D.K., 2006, County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001. U.S. Geological Survey Scientific Investigations Report 2006-5012.

Weissmann, G.S., Zhang, Y., LaBolle, E.M., and Fogg, G.E., 2002, Dispersion of groundwater age in an alluvial aquifer system: Water Resources Research, v. 38, pp. 16-1–16-13.

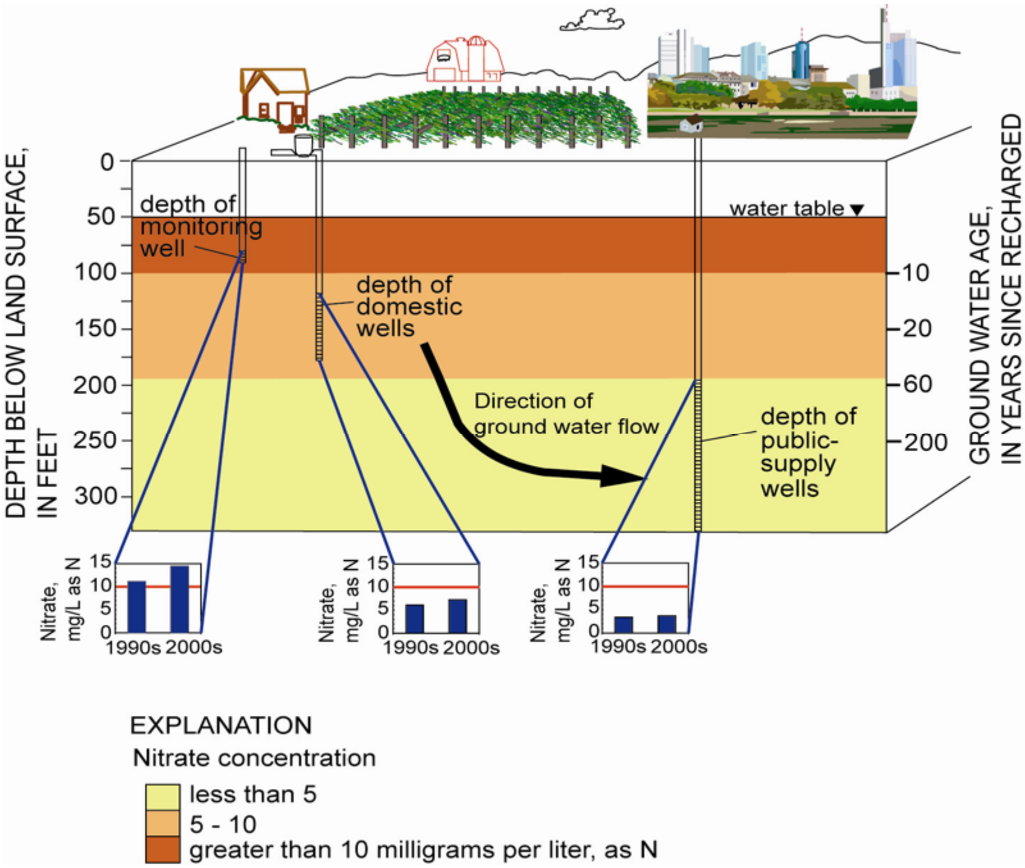

Figure 1. Nitrate concentrations and well depths in areal well networks sampled by the U.S. Geological Survey in the eastern San Joaquin Valley, California (Burow et al., 2007; Burow et al., in press).

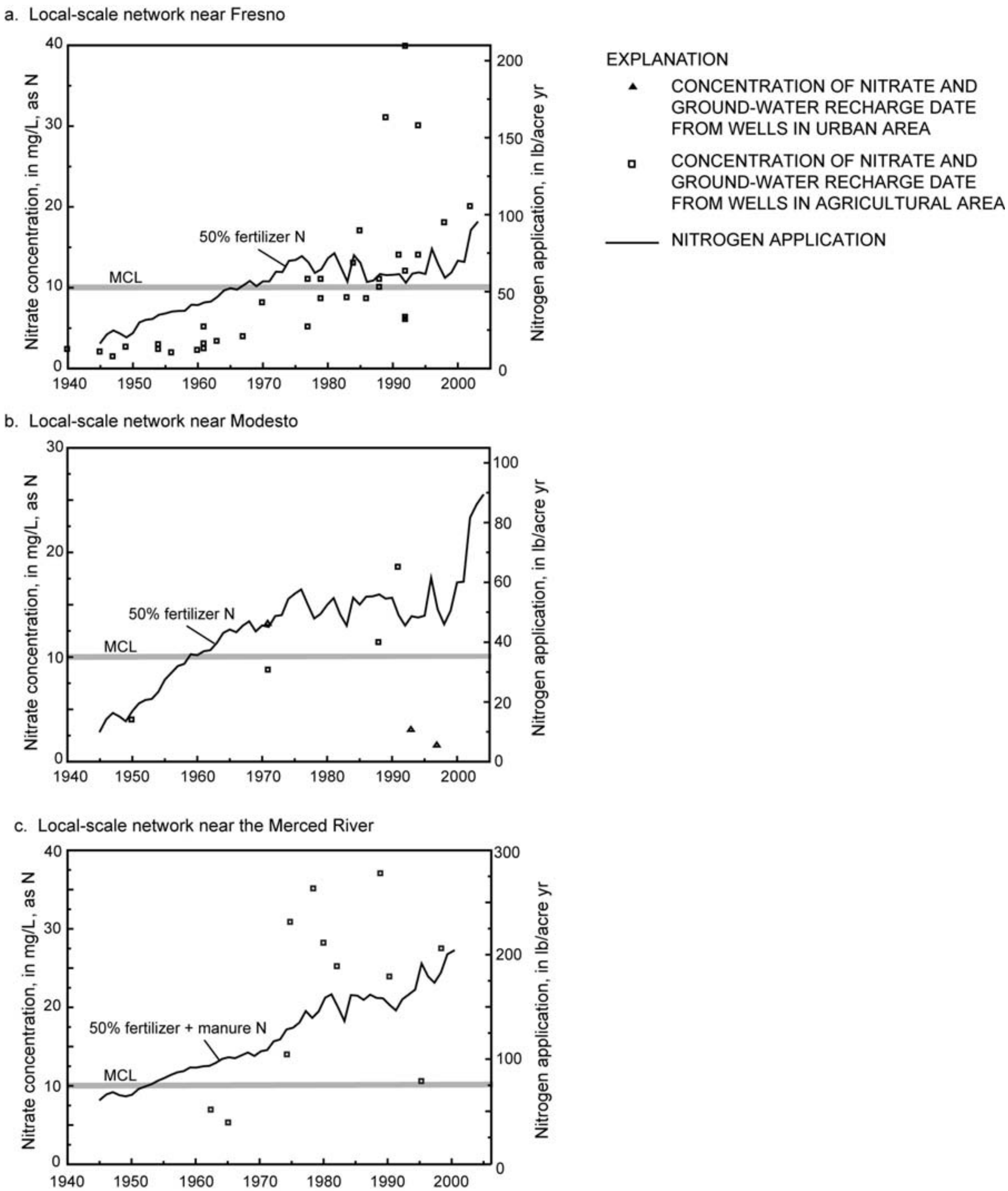

Figure 2. Estimated concentrations of nitrate in recharge and observed concentrations of nitrate in monitoring wells in (a) Fresno, California, (b) Modesto, California, and (c) near the Merced River, California. Nitrogen applications in (c) include manure. Observed concentrations of nitrate are plotted against corresponding dates of groundwater recharge. Estimated concentrations of nitrate from applications represent 50% of the nitrogen fertilizer applications (plus manure at Merced River site) divided by the area of fertilized land, dissolved in 0.6 m/yr of recharge in Fresno and 0.4 m/yr in Modesto and near the Merced River.

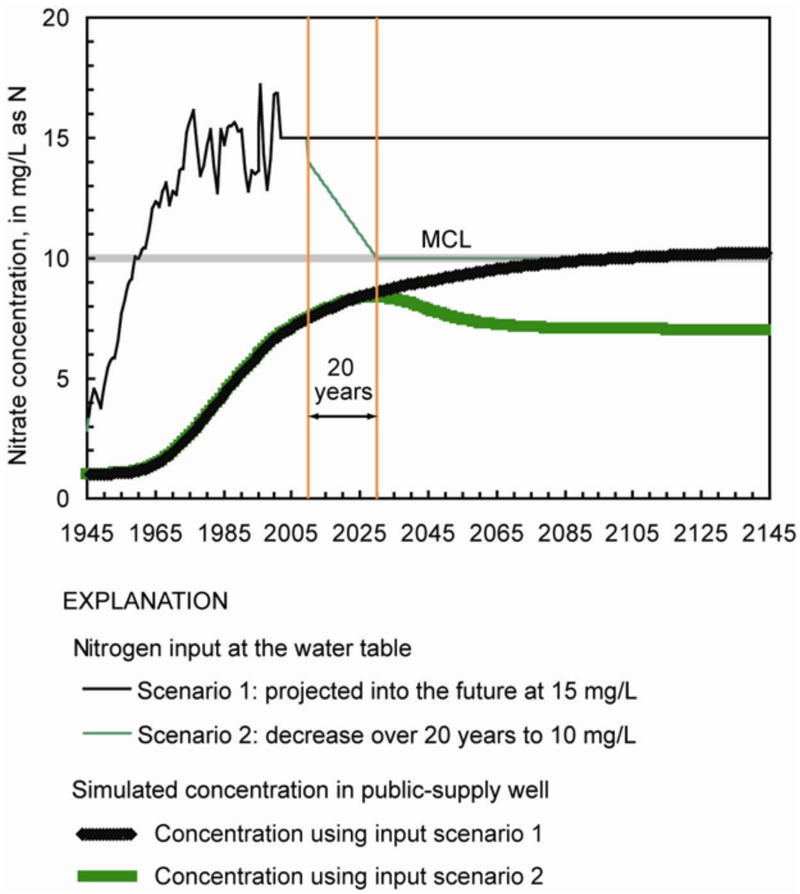

Figure 3. Simulated long-term concentrations of nitrate in a typical public-supply well in the eastern San Joaquin Valley, California. Concentration in public-supply well assumes 100% agricultural land in contributing recharge area; well screen depth about 100 to 400 ft below the water table; first-order denitrification rate constant = 0.005/yr.

Assessing Nitrate Leaching Potential by Hazard Index

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Some of the highest levels of nitrate were found in streams and ground-waters in agricultural areas. An internet-based, interactive hazard index (HI) was developed to assess the relative vulnerability of groundwater to agricultural nitrate contamination in irrigated crop fields. The HI uses factors of soil type, crop, and irrigation system, each with their own hazard rating, to assess the vulnerability, or potential hazard, of a site. Soils are rated on a scale of 1 to 5 while crops and irrigation are each rated from 1 to 4; in each case the relative hazard potential is lowest at 1. By multiplying the values from each factor, the specific site HI can range from 1 to 80 (Table 1). The greatest attention and resource investment can then be directed to areas with a high HI rating, while less concern is given to areas with a low rating. The HI contains a database of over 500 soils and 150 crops in the three southwest states of Arizona, California, and Nevada, with each soil type and crop ranked for their leaching potential. An online soil survey browser was also added to help the users to find their soil series from the maps.

Table 1. Matrix for the overall hazard indices that overlay soil, crop and irrigation.

Crop	Soil 1	2	3	4	5	Irrigation
1	1	2	3	4	5	**1**
1	2	4	6	8	10	**2**
1	3	6	9	12	15	**3**
1	4	8	12	16	20	**4**
2	2	4	6	8	10	**1**
2	4	8	12	16	20	**2**
2	6	12	18	24	30	**3**
2	8	16	24	32	40	**4**
3	3	6	9	12	15	**1**
3	6	12	18	24	30	**2**
3	9	18	27	36	45	**3**
3	12	24	36	48	60	**4**
4	4	8	12	16	20	**1**
4	8	16	24	32	40	**2**
4	12	24	36	48	60	**3**
4	16	32	48	64	80	**4**

GIS/Aerial Imagery Applications

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Introduction

Since 2003 Britz Fertilizers Inc. has supplied imagery Data to the sales staff and to customer on a pay per acre. The data collected was LandSat Satellite Data, QuickBird Satellite Data, Aircraft data. The data was originally to be used for Variable rate pesticides and fertilizers. The data is being distributed using the World Wide Web.

Data Collection

Britz Fertilizers Inc. started a Precision Ag program in late 2001 with grid Soil Sampling. The grid samples was setup on two and a half (2.5) acre grids which produced lots of data, but was extremely costly. The grid sample method required equations similar to this:

Description:
Equation output: Calcium Sulfate (gypsum) (Tons (US) per Acre)
Minimum application rate: 0 (t/ac)
Region of applicability: Any crop
Input data
Name Data group Unit Data
Na soil_test ppm Na Mehlich III
Ca soil_test ppm Ca Mehlich III
Mg soil_test ppm Mg Mehlich III
DESIRED other val
'UC_GYP_REC= 1.7*(NAPPM/229.9-((DESIRED/100)*((NAPPM/229.9)/((0.01475*SAR)-0.0125))))"
%SAR = Na / sqrt ((Ca + Mg) / 4)
apply (1.7 * (Na / 229.9 - ((DESIRED / 100) * ((Na / 229.9) / ((0.01475 * %SAR) - 0.0125)))))

The problem associated with equations are extensive: Grid size versus the cost of return, the time to write crop specific equations, lab cost and the ability to pull soil samples in a timely manner.

In 2001 LandSat images were purchased and developed into Normalized Vegetation Index (NDVI). . The LandSat satellite passes over and same location on earth ever 16 days. The data collection remains consentient for the life of the satellite. All LandSat images that have less than ten percent cloud cover over critical areas are purchased. The NDVI images have a color table applied, which show the reflection for a specific crop at a given life stage. A single image is chosen by the Farmer/PCA/advisor and a map was created using proprietary software. Using the created map and the NDVI image soil samples are pulled from known locations using GPS. Using the lab results, the pesticides or fertilizer are assigned to the map, and given to the applicator. Multi-bin applicators are used for most of the products that are applied.

The raw data is 28.5 meter (93.5 feet) pixels, with a finished product of 14.25 meters or 46.75 feet per pixel. When comparing grid soil sampling to LandSat data you would have to pull five samples per acre to collect the same relative data. Images collect more data quickly and are consistent. Images are not a cure all, but a tool that are readily available in a commercial setting.

The grower/PCA/Advisor makes the recommendation, not the software. This allows for more local control taking into consideration the Grower's knowledge of his field, the dollars to be spent and the return on the dollar expected.

Other uses of imagery include land use changes over time, drift of herbicides into surrounding crops, analysis of algorithms from special features like the Tree and Vine Health Index, Tree and Vine Counts, Harvest by color or areas, Irrigation systems failures and repairs.

In 2003 Britz Fertilizers Inc. added high resolution images which included data sources like the QuickBird Satellite and Airplane Images. These images are one meter pixels (3.28 feet) or sub meter pixels.

The product of tree grading was added in 2005. This gives the end user a tree count and a comparison for each individual tree when looking at a whole field or grove. The data can be used for early order of replacement trees and vines.

The next step in the progression will be drones similar to the military predator drone. The drones will be automated and once launched will fly completely on it's on, collecting images and return to the launch site. The data would be processed, and within a few hours distributed.

All images are calibrated prior to distribution to eliminate errors and maintain data integration for use when comparing image to image. The LandSat data scene is large, and measures larger than 100 miles square. The data is cut or broken down into smaller areas, generally about 24 square miles, so that these images can be opened in a PDA or similar device for ease of use in the field. Add a handheld GPS device and the images can be used for scouting in the field.

Data Distribution

The data is posted to www.britzinc.com, and when supplied with a user name and password the data can be downloaded, unzipped and used on a local machine. The images will open in most GIS programs like Arcview, MapInfo, Google Earth and most Pocket PC software. The data is geo-referenced and used UTM projections for the raster images. The old saying a picture is worth a thousand words applies.

Currently Britz Fertilizers Inc. services over 90,000 acres using high and low resolution imagery. LandSat data cost around $2.00 dollars per acre for a years worth of collected data. This guarantees six images during one year. The high resolution one meter data cost $3.50 dollars per acre per image series. The tree grading with the image cost $5.00 dollars per acre per image. Multi high resolution images, three or more, may be ordered with the tree grading for a cost of $11.00 dollars when ordered prior to spring.

Modern Concepts in the Management of Saline Soils and Irrigation Supplies

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Introduction

Existing water quality guidelines and recommendations for salinity management are based on early research conducted by USDA-ARS Salinity Laboratory and University of California researchers. These were recommendations established at a time when irrigation projects were under development and there was abundant high quality water for irrigation. Water quality criteria were based on the response of laboratory soil column experiments of saturated hydraulic conductivity using waters of various EC and SAR (sodium adsorption ratio) as well as qualitative general field observations of plant vigor and soil appearance under a variety of SAR conditions. Plant response to salinity was determined under greenhouse or sand culture cultivation, primarily with Na-Cl or Ca-Na-Cl salts added to nutrient solutions. Reclamation of sodic soils was based on calculation of the gypsum or sulfur amendment needed to supply the calcium to change the exchangeable sodium in the soil to below a specified value, typically 5-15% of the cation exchange capacity. Leaching requirements were based on quantities of water necessary to reduce the soil salinity to below a specified value where yield loss would not occur. These recommendations were successfully utilized in reclamation of saline and sodic soils and development of our large irrigation projects throughout the western U.S.

At the present time there is a shortage of high quality water in the southwestern U.S. and irrigated agricultural acreage is declining. This decline is due to shortages of water, related to reductions in deliveries as a result of drought, court mandated surface water flow releases for environmental concerns, purchases of irrigation water by municipal water organizations, and restrictions on discharge of drainage waters. Increasing demands on our fresh water supplies means that irrigated agriculture will need to look to alternative sources of water, including reuse of drainage water, treated municipal and industrial waste waters, and brackish ground waters. These waters are invariably higher in salinity than the currently utilized fresh waters, with the added salinity often being primarily sodium and chloride. These conditions require renewed attention to salinity management and current recommendations.

Current water quality criteria were developed as simple criteria designed to avoid problems under most conditions. Consideration of site specific conditions is necessary for better water utilization. Many waters considered unsuitable have value under specified climatic, soil and management conditions. Rather than classification of waters as suitable and unsuitable it is more useful to develop predictive relationships that describe how certain water quality parameters impact crop and soil responses.

Water Quality Criteria for Irrigation

Water suitability for irrigation and sodicity hazard related to infiltration has been established primarily from laboratory experiments, almost all based on short term column experiments of saturated hydraulic conductivity with waters of decreasing electrical conductivity (EC) and constant sodium adsorption ratio (SAR). In most irrigated areas rain is an important factor in the soil water budget and of the resultant chemical and physical conditions. We have examined both calcareous soils from the Upper Great Plains of the U.S. and a non calcareous soil from the arid southwestern U.S. in year- long outdoor studies with conditions of combined simulated rain and irrigation and wetting and drying cycles with waters of varying SAR and at an electrical conductivity of either 1.0 and 2.0 dS/m, and varying pH. Rain has an adverse impact related to the SAR of the soil water at the time of infiltration. Contrary to results from column studies, there were little differences in the infiltration results from the two salinity levels. Based on these studies, we conclude that when considering rain as well as irrigation water, there is no threshold SAR value at which there is a reduction in soil infiltration. Any increase in SAR above the control results in a reduction in infiltration (Suarez et al. 2006, Suarez et al. 2008). These results indicate a need to modify the Ayers and Westcot (1985) guidelines, as proposed. The impact of decreasing infiltration depends on site-specific conditions. For example for sandy soils a 20% reduction in infiltration over the course of a year is not significant but for a clay soil with limited infiltration, the impact could result in a corresponding reduction in water availability and crop yield.

In addition to EC and SAR there are other important factors that impact water suitability related to infiltration. Elevated pH adversely impacts infiltration, especially above pH 8, based on experiments conducted at constant EC and SAR (Suarez et. al. 1984). Soils also differ in terms of their susceptibility to SAR, related to clay type, organic matter content, oxide content, among others. Climatic conditions (ET_0), crop water demands, irrigation system, tillage and other management practices also impact the adverse effect of sodium on infiltration. Degraded waters generally contain increased levels of alkalinity (thus elevated pH) and often contain elevated concentrations of minor elements such as boron that may adversely affect crop growth. In many instances use of these waters may be judged unsuitable based on steady state considerations however transient conditions suggest conditions under which they may be used. Examples are given for model simulations using high boron waters for irrigation and suggestions for optimal management.

Irrigation Water Salinity and Leaching Requirement

Leaching requirements for salinity control have been based on steady state analysis of irrigation water with simplifying assumptions about the relation of EC of soil water extract to EC of soil water, how plants integrate water uptake and soil salinity, and sensitivity to salts at different stages of growth. Converting soil water salinity to the salinity of the water extracted by the plant is generally done by specifying a leaching fraction.

The salt tolerance of plants is reported in terms of the saturation extract EC. This is considered to provide a good reference water content for comparisons among experiments and field conditions. However, plants respond to soil water EC and that of the actual, not reference, water content. Simple conversions of soil water (generally at field capacity) to saturation extract exist but can lead sometimes lead to significant errors. For gypsum containing soils, soil water salinity is considerably lower than estimated. This salinity over-estimation leads to over-estimation of salt damage in gypsum containing soils. Additionally EC is not linear with dilution as assumed, this is usually a minor error but it results in overestimation of the soil water salinity. It is likely that the plant responds to the time integrated salinity- this consideration means that for infrequent irrigation cycles soil salinity is greater than estimated. These factors can be evaluated using the Extract chem. model (Suarez and Taber, 2007).

Extent and timing of rain needs to be considered when evaluating suitability of waters for irrigation. At the present time, rain interactions are generally ignored. As a first approximation we can consider that crops respond to the average of the rain and irrigation water composition, thus indicating improved plant response relative to irrigation only conditions. Where winter rains and leaching occur, soil salinity is reduced during the early stages of crop growth, which are generally the most salt sensitive stages, thus increased salinity may be tolerated.

Because salt tolerant crops are generally lower value crops, and often lower yielding crops, they should not be automatically recommended for saline conditions. Despite some yield loss moderately salt tolerant crops such as alfalfa may out-produce more salt tolerant crops such as wheatgrass at salinities up to 15 dS/m. Additional benefits of moderate salt stress to crops may be increased product quality. Many plants adapt to salt stress by enhanced accumulation of secondary metabolites such as soluble solids, sugars, organic acids, and proteins, thus increasing quality and marketability. For example salinity stress increases sugar and dissolved solids content of tomatoes and melons, increases content of beneficial antioxidant compounds in strawberries and increases oil and particularly the desired lesquerolic acid in lesquerella.

We now have the capability to actively monitor salinity at the field scale. New remote sensing technology can be used to provide rapid and inexpensive detailed field salinity assessments (Corwin and Lesch, 2005, and Lesch, 2006) and site specific management including evaluation of the need for amendments. Using this technology in combination with modeling (Suarez, 2001), allows for site specific leaching and reclamation within a field. Reduction in the use of amendments and leaching water for sodic soil or saline soil reclamation can be achieved by blocking the fields into different gypsum requirement zones, based on variations in clay content and SAR. Current amendment requirements do not consider the significant calcium inputs from dissolution of calcite, thus overestimating gypsum requirements. This reduction in salt loading can be especially important if reclamation occurs in combination with high soil carbon dioxide concentrations (warm soil temperatures combined with wet surface conditions).

Calculation of the leaching requirement is generally based on an assumed water uptake function, then calculation of salinity with depth (4 quarters) assuming EC is inversely related to water uptake. The root zone salinity is next averaged and compared to the published salt tolerance tables. This calculation overestimates the soil salinity experienced by the plant. Precipitation of calcite and the nonlinear interaction of water content and salinity mean that the osmotic pressure or EC is not as high as assumed in the lower depths of the soil. This calculation also does not account for the water uptake function used in the calculation of the soil EC. Plants extract less water from the more saline depths and more water from the surface. This consideration also reduces the estimated salinity experienced by the plant. In addition, consideration that plants respond to salinity by preferentially growing roots and extracting water from non saline regions of the soil may further reduce the calculated need for leaching (Letey and Feng, 2007).

Literature cited

Ayers, R.S., and D.W. Wescot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 rev. 1. Food and Agriculture Organization of the United Nations. Rome 174 pp.

Corwin, D.L. and S. M. Lesch. 2005. Apparent electrical conductivity measurements in agriculture. Computers and Electronics in Agriculture 46:11-45.

Lesch, S.M. 2006. Statistical software package for estimating field scale spatial salinity patterns from electromagnetic induction signal data ESAP v. 2.35. http://www.ars.usda.gov/Services/docs.htm?docid=8918

Letey. J. and G.L. Feng. 2007. Dynamic versus steady-state approaches to evaluate irrigation management of saline waters. Agric. Water Manage. 91:1-10.

Suarez, D.L. 2001 Sodic soil reclamation: Model and field study. Aust. J. Soil Res. 39:1225-1246.

Suarez, D.L., J.D. Rhoades, R. Lavado and C.M. Grieve. 1984. Effect of pH on saturated hydraulic conductivity and soil dispersion. Soil Sci. Soc. Am. J. 48:50-55.

Suarez, D.L. and P. Taber. 2007 Extract Chem model to predict major ion and boron composition of a soil solution at a desired water content. http://www.ars.usda.gov/Services/software/download.htm?softwareid=155

Suarez, D.L., J.D. Wood and S.M. Lesch. 2006. Effect of SAR on water infiltration under a sequential rain-irrigation management system. Agric. Water Manage. 86:150-164.

Suarez, D.L., J.D. Wood and S.M. Lesch. 2008. Infiltration into cropped soils: Effect of rain and SAR – impacted irrigation water. J. Environ. Qual. (In review).

Is Drip Irrigation Sustainable Under the Shallow, Saline Ground Water Conditions of the San Joaquin Valley?

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The Current Situation

After more than 30 years of research along the west site of the San Joaquin Valley, no wide-spread economically, technically, and environmentally feasible drain water disposal methods have been implemented in the valley. In some areas, land retirement is being implemented as a solution. The only options available to growers to address the salinity/drainage problem other than land retirement are better management of irrigation water to reduce drainage, increase crop water use of the shallow groundwater without any yield reductions, and reuse drainage water. One option is to convert from furrow or sprinkler irrigation to drip irrigation.

Between 1998 and 2003, experiments in commercial fields in the Westlands Water District (on the west side of the San Joaquin Valley) evaluated the effect of subsurface drip irrigation of processing tomatoes under saline, shallow ground water conditions. In addition, in 2006, computer simulation using the HYRUDS-2D computer model (Šimůnek et al., 1999) evaluated leaching with subsurface drip irrigation under these conditions. A summary of this research is presented herein.

Commercial Field Experiments

Subsurface drip irrigation of processing tomatoes was highly profitable under shallow saline ground water conditions (Hanson and May, 2003; Hanson and May, 2004). Average yields of three commercial fields were 40.5 tons per acre and 33.9 tons per acre for subsurface drip irrigation and sprinkler irrigation, respectively, which resulted in an average of $484/ac more profit for drip irrigation than for sprinkle irrigation. Yields of the drip-irrigated fields remained high during the project period except at one site which had two years of reduced yields due to late plantings. No trend in yield with soil salinity levels near the drip lines was found at these sites.

At the fourth commercial field where both tomatoes and cotton were grown, tomato yield ranged 34.6 tons/ac for 15.6 inches of applied water to 42.8 tons/ac for 23.2 inches (about equal to the seasonal evapotranspiration of tomatoes) (Hanson et al., 2006). No yield response to irrigation water amounts occurred for cotton. The water table depth was smaller than 2 feet.

Soil salinity levels around drip lines depended on the depth to the ground water, salinity of the shallow ground water, salinity of the irrigation water, and amount of applied water. A water table depth of about 6 feet resulted in a relatively uniform distribution of soil salinity throughout the profile with values smaller than the threshold ECe of 2.5 dS/m for tomatoes (fig. 1A). For water table depths less than about 3 feet, relatively small levels of soil salinity occurred near the drip line with higher values near the periphery of the wetting pattern (fig. 1B and C). Larger amounts of applied water increased the zone of low salt soil near the drip line even under shallow water tables depths smaller than 2 feet (data not shown).

The key to profitable subsurface drip irrigation of tomatoes in these salt affected soils is salinity control in the root zone by leaching or flushing of salts from the root zone. The leaching fraction, used to quantify leaching adequacy, is the ratio of the amount of water that drains below the root zone to the amount applied.

A common approach used to estimate leaching fractions is the water balance method which calculates the field-wide amount of leaching as the difference between seasonal amount of applied water and evapotranspiration (ET). Calculated field-wide leaching fractions of the commercial fields showed little or no field-wide leaching at most of the sites (table 1), which suggests inadequate salinity control and raises questions about the sustainability of drip irrigation under these saline, shallow ground water conditions. The soil salinity data, however, clearly showed that substantial leaching was occurring around the drip lines (referred to as localized leaching herein) and that the leaching was highly concentrated near the drip line. The soil salinity data indicated that the water balance approach is not appropriate for drip irrigation and that estimating actual or localized leaching fractions under drip irrigation may be difficult.

Computer Simulations

The computer model HYDRUS-2D was used to evaluate leaching with subsurface drip irrigation under saline shallow ground water conditions found at the commercial fields and to estimate actual leaching fractions. This model simulated the movement of water and salt in soil under drip irrigation for a 42 day period and determined the amount of drainage below the root zone. Simulations were conducted for water table depths of 20 inches and 40 inches, irrigation water salinities of 0.3, 1.0, and 2.0 dS/m, and applied water amounts of 80, 100, and 115 % of the potential evapotranspiration. For the 0.3 dS/m irrigation water, an additional simulation was conducted for a water application of 60%. The drip line was 8 inches deep. Two irrigations per week occurred for the 40 inch water table depth and daily irrigations occurred for the 20 inch depth. The EC of the shallow ground water was 10.0 dS/m and 8.0 dS/m for the 20 and 40 inch water table depths, respectively, based on measured levels. The initial soil water salinity levels at the start of the simulation period were based on soil salinity collected in the spring, prior to drip irrigation.

Reclamation of the soil near the drip line was rapid with salinity patterns consistent with those found in the commercial fields (data not shown) (Hanson et al., 2007). The volume of reclaimed soil increased over time with most of the reclamation occurring below the drip line. Salts accumulated near the soil surface. Larger seasonal amounts of applied water increased the zone of low salt soil near the drip lines (consistent with field data), but the larger amounts had little effect on the volume of reclaimed soil above the drip line. Salinity near the drip line increased as the irrigation water salinity increased.

Actual or localized leaching fractions ranged from 7.7% (60% water application) to 30.5% (115% water application) and was 24.5% for the 100% water application (table 2). Thus, even for water applications equal to or smaller than 100% of the potential evapotranspiration (ET_{pot}), drainage occurred below the root zone caused by the spatially-variable wetting under drip irrigation.

A common assumption is that an amount of applied water equal to 100% ET_{pot} results in an irrigation efficiency of 100% for drip irrigation, and little or no drainage occurs. The computer simulations showed that this assumption is not true and that water applications equal to 100% ET_{pot} resulted in irrigation efficiencies of 74.6% and 69.7% for the 100 cm and 50 cm water table scenarios, respectively. Very high irrigation efficiencies occurred only under severe deficit irrigation conditions.

Conclusions and Recommendations

Conclusions of both field research and computer simulation modeling are:

- Subsurface drip irrigation of processing tomatoes is highly profitable compared to sprinkle or furrow irrigation under saline, shallow ground water conditions.
- Tomato yield increased as applied water increased; cotton yield was unaffected by applied water amounts.
- Root uptake of the saline, shallow ground water by tomatoes should be minimized to prevent yield reductions; substantial root uptake of the ground water by cotton can occur without yield reductions.
- Considerable localized leaching occurs around the drip lines due to the wetting patterns that occur under subsurface drip irrigation. The localized or actual leaching fraction was about 25% for a water application equal to 100% of the potential evapotranspiration.
- The localized leaching is highly concentrated near the drip line, resulting in relatively low soil salinity levels in the area where root density has been found to be the highest under subsurface drip irrigation of processing tomatoes.
- Because of the localized leaching, the water balance approach is inappropriate for drip irrigation.
- Little water table response to drip irrigation occurred except when over irrigation occurred.
- Reclamation around newly installed drip lines in saline soil was rapid. The reclamation was faster for relatively large water applications per irrigation applied less frequently than for smaller applications per irrigation applied more frequently.
- The low salt zone around the drip line increased as the amount of applied water increased.
- Soil salinity around the drip line increased as the salinity of the irrigation water increased.
- Very high irrigation efficiencies under drip irrigation can only be obtained by substantial deficit irrigation. This contrasts the assumption frequently made that drip irrigation is nearly 100 % efficient for water applications equal to about 100% of the potential evapotranspiration.

Subsurface drip irrigation is sustainable as long as adequate salinity control around the drip line occurs. Recommendations for sustainable subsurface drip irrigation under saline, shallow ground water conditions are:

• Seasonal water applications should be about equal to the seasonal evapotranspiration. This amount of water provides sufficient localized leaching. Higher applications could raise the water table, thus causing saline, shallow ground water intrusion into the root zone; smaller applications reduce the tomato yield.

• The electrical conductivity of the irrigation water should be about 1.0 dS/m or smaller. Higher EC levels may reduce yield.

• Daily to two to three irrigations per week should occur. Daily irrigations are recommended for very shallow saline ground water.

• Periodic leaching of salt accumulated above the buried drip lines will be necessary with sprinkle irrigation for stand establishment if winter and spring rainfall is insufficient.

• Drip irrigation systems should be designed for a high uniformity of applied water.

• Drip irrigation systems should be properly maintained to prevent emitter clogging.

Can drip irrigation eliminate the need for subsurface drainage systems and drainage water disposal methods? No subsurface drainage systems were used at these sites. Water table depths ranged from several feet to about 6 feet. At all sites, ground water salinity was high No trend in yield with water table depth or soil salinity occurred. Subsurface drip irrigation continues to be used at these sites along with many other fields along the west side.

Little response of the water table to drip irrigation occurred at these sites except at one site when overirrigation occurred. Although drainage below the root zone occurred under subsurface drip irrigation, as shown by the simulations, the amount of drainage per irrigation was small because of the small water applications per irrigation, and because of the high irrigation frequency, its distribution over time was relatively uniform. As a result, the natural subsurface drainage in these fields appeared to be sufficient to prevent ground water intrusion into the root zone. This behavior suggests that, for the conditions found in these fields, subsurface drainage systems and drainage water disposal methods are not needed for properly managed and designed drip irrigation systems. For locations where the water table is affected by drip irrigation, subsurface drainage systems and disposal methods may be required.

Literature Cited

Hanson, B. R., May, M. 2003. Drip irrigation increases tomato yields in salt-affected soil of San Joaquin Valley. California Agriculture 57(4):132-137.

Hanson B.R., May, D.M. 2004. Effect of subsurface drip irrigation on processing tomato yield, water table depth, soil salinity, and profitability. Agricultural Water Management 68:1-17.

Hanson, B.R., Hutmacher, R.B., May, D.M. 2006. Drip irrigation of tomato and cotton under shallow saline ground water conditions. Irrigation and Drainage Systems 20:155-175

Hanson, B.R., Šimůnek, J., Hopmans, J.W. 2007. Leaching with subsurface drip irrigation under saline, shallow ground water conditions. *Vadose Zone Journal*, in press.

Šimůnek, J., Šejna, M., van Genuchten, M. Th. 1999. The HYDRUS-2D software package for simulating two-dimensional movement of water, heat, and multiple solutes in variably saturated media. Version 2.0, *IGWMD-TPS-53*, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado. 251 pp.

Table 1. Seasonal applied water, evapotranspiration, and leaching fractions calculated from a water balance for the four commercial sites. BR, DI, DE, and BR2 are the location identifiers.

Year	**Seasonal applied water (inches)**	**Seasonal evapotranspiration (inches)**	**Leaching fraction (%)**
BR			
1999	16.0	20.3	0
2000	16.8	21.4	0
2001	20.5	22.9	0
DI			
1999	22.2	25.1	0
2000	29.0	25.2	13.1
2001	22.9	26.6	0
DE			
2000	28.8	24.2	13.6
2001	22.1	23.1	0
BR2			
2002	23.2	24.3	0

Table 2. Actual or localized leaching fractions determined with the HYDRUS-2D computer simulation model for the 40 inch water table depth and a 0.3 dS/m irrigation water.

Applied water (%)	Actual leaching fraction (%)
60	7.7
80	17.3
100	24.5
115	30.9

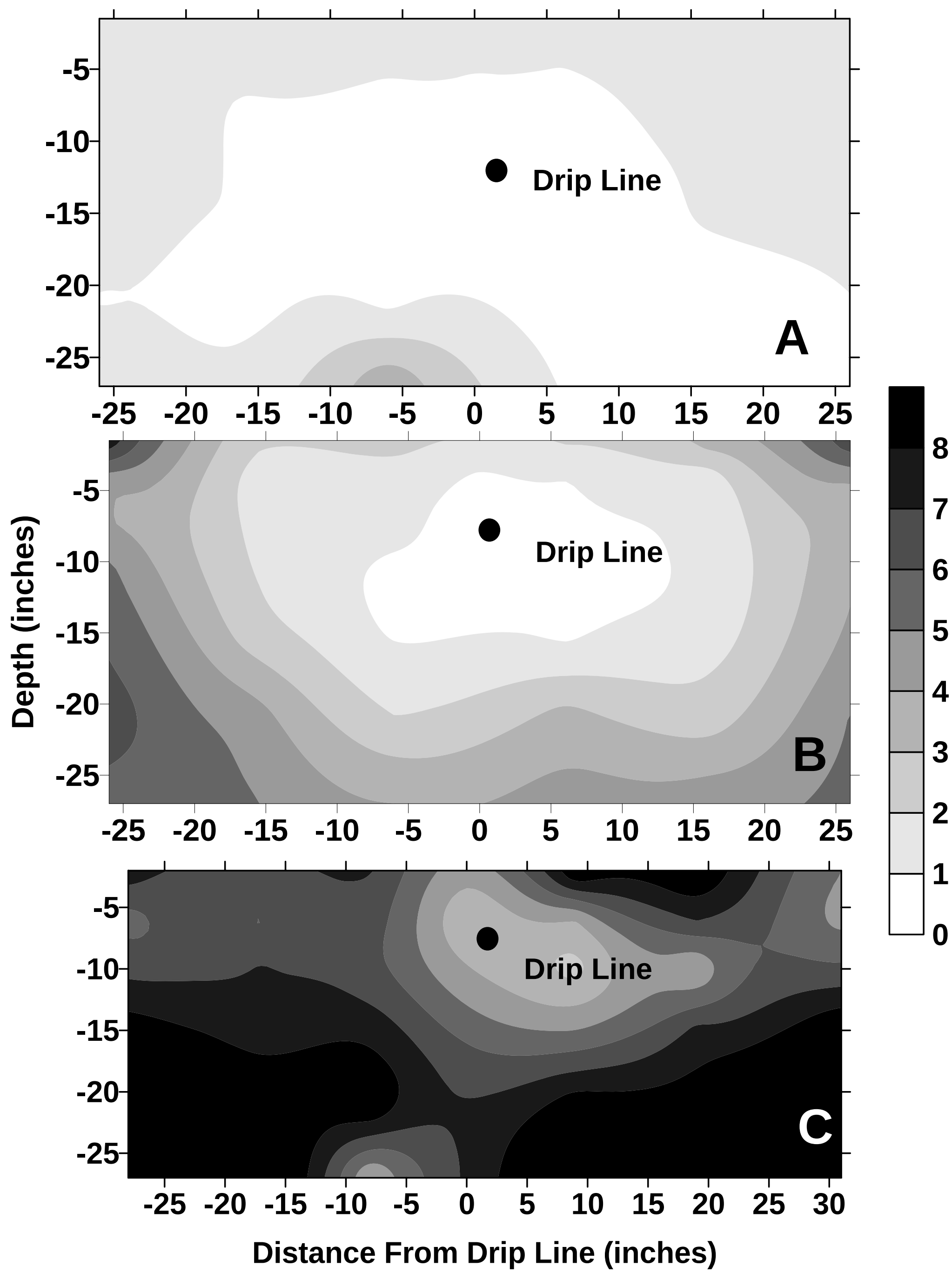

Figure 1. Patterns of soil salinity around drip lines for (A) water depth of about 6 feet, electrical conductivity (EC) of irrigation water = 0.3 dS/m, and EC ground water = 8 to 11 dS/m; (B) water depth of about 2 to 3 feet, EC of irrigation water = 0.3 dS/m, and EC ground water = 5 to 7 dS/m; and (C) water depth of about 2 to 3 feet, EC of irrigation water = 1.1 dS/m, and EC ground water = 9 to 16 dS/m. Soil salinity is expressed as the EC of the saturated extract.

Pistachio Salinity Tolerance and Development with Interplanted Cotton

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Abstract

A 9-year small-scale trial (ending 2002) in the southern San Joaquin Valley found that established pistachios can tolerate an irrigation water salinity up to 8 dS/m (similar to cotton) without a reduction in yield.

In 2004, a shallow subsurface drip tape system was installed in two 155 acre fields to irrigate future pistachio tree rows 22 feet apart with 4 rows of cotton interplanted on 38 inch beds. Replicated 19.5 acre blocks were arranged to test plant response to fresh (canal) water, blend and saline well water treatments with EC of 0.5, 3.0 and 5.4 dS/m and boron @ 0.3, 6 and 11 ppm, respectively. Fresh water was used to germinate cotton, which was planted in 2004, 5 and 6. Pistachios were planted in 2005. Cotton yields were unaffected by salinity, until 2006; showing a half bale loss for the well water (3.12 bale/ac) compared to the canal water (3.68 bale/ac). Pistachio growth is unaffected by salinity after 3 years.

Introduction

Cotton has long been known as a salt tolerant crop, but despite many small-scale field trials over 30 years almost no marginally saline water in the San Joaquin Valley is used for long-term production Over this same period water costs have increased four to tenfold while acala cotton prices have increased little since the early 1960's. At the same time, the population of California has grown by 10 million people and ag demand has dropped from 26 to 25 MAF mostly due to the adoption of micro (drip) irrigation systems (Table 1). Farmers are looking for less expensive, more secure water supplies and more profitable crops.

Table 1. Changes in California irrigated acreage by system, ag water demand and population from 1970 to 2000. (Irrigation Association)

Year	1970	2000
Total Irrigation (MAc):	8.7	9.6
Gravity	7.2	5.1
Sprinkler	1.5	2.8
Micro	0.0	1.7
Ag demand (MAF):	26.0	25.0
Avg Water Cost ($/ac-ft):	$18	$85
Population:	25.1	35.4
Municipal demand (MAF):	5.0	6.4
Ag Demand/Total:	84%	80%
Ag Demand (ac-ft/ac):	3.00	2.60
Ag Savings (%):	Base	13%

The need for alternative water supplies was made very clear when State Water Project allocations to Westside irrigation districts went to zero in 1990 due to extended drought; unleashing California's infant water market with the establishment of "Emergency Pool" water that could be bought for $100/ac-ft. Given the salt tolerance of cotton and other rotation crops on the Westside (such as processing tomatoes), some studies investigated utilizing fresh water blended with drainage from tile systems as a means of boosting available water supplies for furrow irrigation (Ayars et al., 1993, Sheenan et al., 1995). This approach generated some interest, since yields were maintained at similar levels to fresh water irrigations, but required a high degree of management with the possibility of long-term residual salinity problems that growers did not want to deal with.

At the same time water supplies have decreased and costs have soared, subsurface drip irrigation (SDI) systems using improved, thin-walled drip tape have become cheaper and more profitable than the earlier prototypes of the mid 1990's (Fulton et al., 1991), with capital costs as low as $800/acre for grower installed systems. With a much lower energy requirement than sprinklers, greater uniformity and reduced loss to evaporation (a total savings of 6 to 8 inches) this type of system becomes the most cost effective in this setting. All these factors have combined to make the time right for developing irrigation system management approaches that can use hybrid fresh and saline water supplies to irrigate salt tolerant crops.

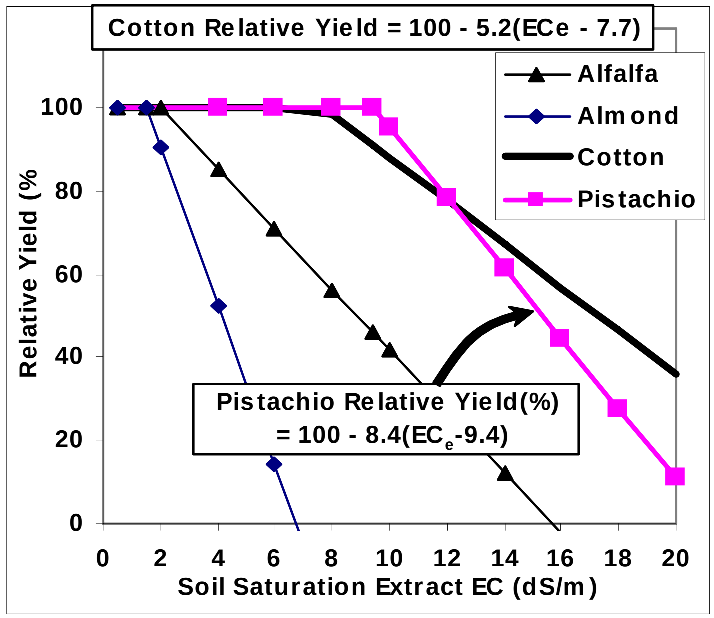


Fig. 1. Comparison of salt tolerance thresholds and relative yield for various crops (Sanden, et.al., 2004)

A recently completed nine year field study on the salt tolerance of pistachios on the Westside of the San Joaquin Valley (Ferguson et. al., 2003 and Sanden, 2004), and previous pistachio studies in Iran (Fardooel, 2001) have shown the viability of using saline water up to 8 dS/m for irrigating these trees (Figure 1). A rootstock trial in sand tanks at the USDA Salinity Lab in Riverside (Ferguson et al., 2002) showed a significant increase in leaf burn when 10 ppm boron was added to irrigation water but no reduction in the biomass of year old trees. The salinity and B tolerance of cotton has been reported at similar levels in tank trials (Ayars and Westcott, 1985) and investigated in long-term field trials (Ayars et al., 1993). Thus, a large-scale trial was initiated in 2004 over 310 acres in the Belridge Water District (NW Kern County) to prove the viabilility of this concept on a production basis.

Project Objectives

- Assess the viability of large-scale cotton production and pistachio interplanting using saline groundwater (up to EC 5 dS/m and B @ 10 ppm) and optimal irrigation scheduling with SDI.
- Determine crop ET as a function of salinity using simple water and chloride balance.
- Maintain acceptable soil salinity levels for cotton stand establishment/production and maximum growth of young pistachios.
- Compare total project profitability under SDI using 3 different levels of salinity: saline water, non-saline CA Aqueduct water and a 50/50 blend. Compare the economics of drip tape SDI with typical Belridge Water District cotton production using sprinklers.

Procedures

A large-scale grower in the Belridge Water District of NW Kern County started pumping brackish groundwater for an experimental drip tape field of cotton in 2003; with the intent of interplanting pistachios in the following years. Pumping and well depreciation costs for this water are about $50/ac-ft compared to $120+/ac-ft for California Aqueduct water. The regional salinity of this groundwater varies from 3 to 8 dS/m with 8 to 12 ppm boron.

Starting in 2004, twelve 19.5 acre test plots were set up in a randomized complete block design in two adjacent 155 acre fields to test the use of saline water for commercial-scale cotton production and development of a new pistachio orchard using shallow sub-surface drip tape (SDI). With each plot nearly 20 acres in size, the 240 acres dedicated to this trial is possibly the largest replicated saline irrigation test ever attempted in the SJV. Irrigation treatments are:

Control:	Aqueduct water only:	EC ~ 0.5 dS/m (300 ppm TDS), Boron 0.3 ppm
Blend:	50/50 mix Aqueduct and Well:	EC ~ 3.5 dS/m (2200 ppm TDS), Boron 6.0 ppm
Well:	Groundwater only:	EC ~ 5.5 dS/m (3500 ppm TDS), Boron 11 ppm

The highest salinity treatment is more than 4 times as saline as almost all irrigation waters currently used in the SJV. The SDI system allows the grower to meet the much higher cotton water demand while avoiding saturation of the young trees – thus maintaining critical cash flow during the early years of orchard development.

The field was planted to solid pima cotton in 2004. Pioneer Gold (PG1) rootstocks were planted in March 2005 to an 18 x 22 foot spacing inter-planted with four 38 inch rows of pima cotton. A set of 10 trees in the middle of each 19.5 acre plot, along with the adjacent cotton is used for intensive monitoring and sampling. A total of 23 UCB rootstocks were also planted adjacent to these monitoring areas. Pistachios were budded with a Kerman scion in July. All plots are irrigated with a total of 8 to 12 inches of fresh (Aqueduct) water (wetted area basis)

Table 2. Plant tissue nutrients, selected salts, growth characteristics, yield and applied salts for cotton and

PLANT TISSUE ANALYSIS	Na (ppm)	Cl (%)	B (ppm)	Root-zone EC_e to 5 ft (dS/m)	[1]Cotton Ht, Pistachio Circum (inch)	Cotton Lint Yield (lb/ac)	[2]Total Salts Applied in Irrigation (lb/ac)
2004	Cotton Petioles 8/27			10/6/04	9/14/04	10/6/04	Cotton'04
Aque	570	2.58	34	2.71	42.2	1933	2,343
50/50	712	**3.23	37	*4.08	*35.8	1928	11,390
Well	574	*3.00	37	*4.68	38.8	2016	21,444
2005	Cotton Petioles 9/15			10/18/05	9/15/05	10/19/05	Cotton'05
Aque	605	2.71	42	1.42	41.6	954	2,305
50/50	539	*3.13	46	3.71	43.1	1129	10,144
Well	546	**3.38	**50	*4.74	42.1	999	16,975
	Pistachio Leaves 9/15			10/18/05	10/19/05		Pistach'05
Aque	222	0.27	194	2.87	2.31		1,742
50/50	220	0.27	**492	4.12	2.17		8,570
Well	314	**0.38	**673	*4.44	2.18		14,782
2006	Cotton Petioles 9/21			10/30/06	9/21/06	10/27/06	Cotton'06
Aque	885	1.95	48	1.01	44.9	1835	1,967
50/50	937	1.91	55	*3.61	45.0	1615	11,046
Well	1143	2.21	*56	**4.63	40.9	*1560	15,832
	Pistachio Leaves 10/31			10/30/06	10/19/06		Pistach'06
Aque	171	0.52	531	2.65	2.58		1,022
50/50	140	*0.58	**954	4.34	2.55		8,994
Well	201	*0.62	**1096	*4.61	2.49		11,104
2007	Pistachio Leaves 6/19				10/18/07		Pistach'07
Aque	99	0.24	167		4.65		1,390
50/50	108	0.28	**315		4.59		7,571
Well	*133	0.30	**384		4.45		13,197

*Significantly different from Aqueduct @ 0.05, **Significant @ 0.01

[1]Cotton height @ irrigation cuttoff.

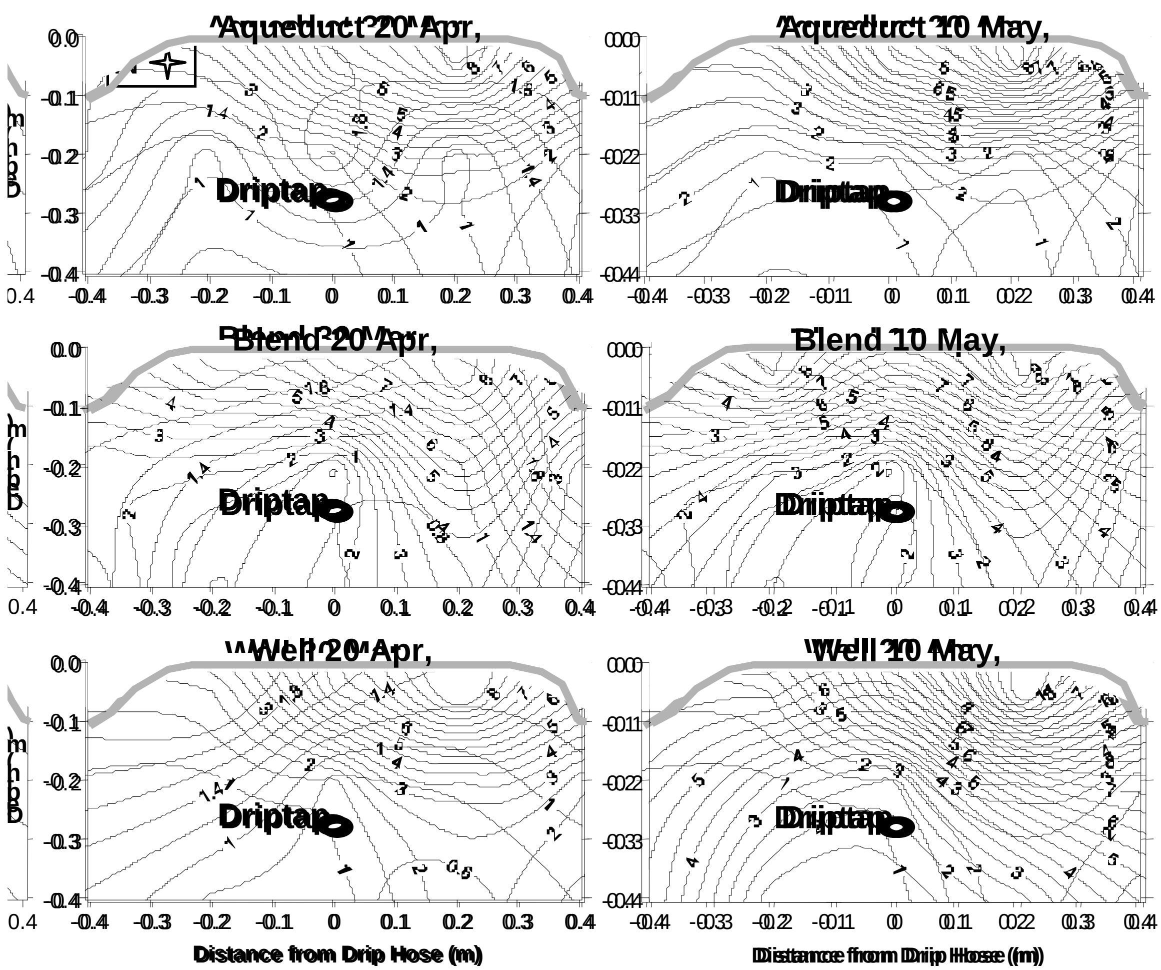
[2]Cotton cover = 12.7 foot width/tree row Pistachios = 9.3 foot width/tree row

during the winter and/or cotton germination, followed by 18 to 26 inches of treatment water, depending on seasonal demand. Pistachios receive about 18 inches based on a 9.5 foot wide area between the cotton (7.8 inches for the 22 foot row spacing). Four rows of Pima were again interplanted in 2006. For 2007, the grower's entire Westside cotton program was canceled due to a 40% reduction of district water; leaving only pistachios.. Pistachios only are to be grown for 2008.

Results and Discussion

2004 cotton yield was excellent at around 4 bale/ac (Table 2). In 2005, all cotton yields were disappointing at around 2 bale/acre due to a very cold spring. Yields were unaffected by irrigation water salinity. Comparison of digital aerial analysis of the Normalized Difference Vegetation Index (NDVI) for August 2004 and 2006 showed no treatment impacts on crop vigor across the field. However, final 2006 cotton yields showed a half bale loss for the Well compared to the Aqueduct treatment (3.12 and 3.68 bale/ac, respectively). Again, cool spring temperatures combined with significant increased seedbed salinity in the Well treatment (ECe of 8 to 11, Figure 2) reduced plant population and early season vigor.

Plant tissue analysis showed a significant 0.5 to 3 fold increase in chloride and boron



levels in both cotton and pistachio (Table 2), but produced no toxicity symptoms in 2005. Some marginal burn was seen in the Well treatment in 2006. In 2007, some marginal leaf burn could be seen in all treatments, but did not seem to impact scaffold development or rootstock circumference. Due to small caliper rootstocks at planting and extremely high July 2005 temperatures, a significant number of trees needed to be rebudded Fall 2005. This resulted in only 40% of the PG1 and 4% of the UCB rootstocks having full scaffold development by the end of 2006

However, the UCB rootstock circumference was significantly larger than the PG1. This difference has disappeared as of the end of this third season of 2007 (Figure 3). Scaffold development is complete on all trees (save a few replants), but the orchard as a whole is behind on development of tertiary branches stemming from the primary scaffolds. This is partially the result of two years of interplanted cotton, and the main reason why interplanting new orchards is rarely seen anymore. However, pistachios do not come into commercial bearing until their 7th year; allowing more time for this orchard to "catch up".

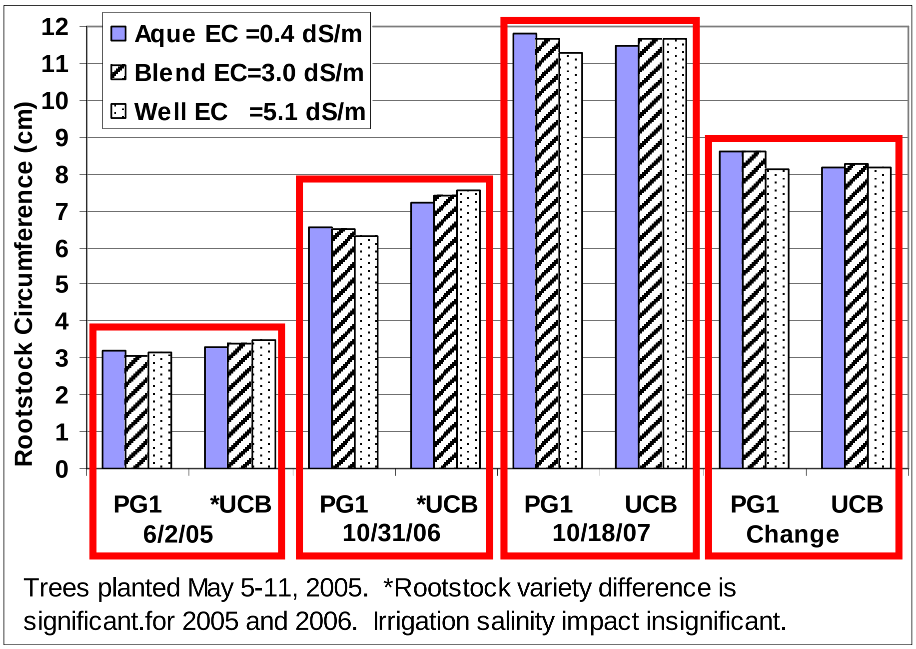


Fig. 3. Mean circumference for PG1 and UCB rootstocks from 40 trees (10 per plot) for all treatments and net increase after three seasons.

After three seasons of cotton irrigation this program results in about 6,600 lb/ac applied salt in the Aqueduct treatment and about 54,000 lb/ac in the Well treatment (Table 2). The final salt load in the 9 foot band along the pistachio drip tape after 3 years will be about 4,000 and 40,000 lb/ac for the Aqueduct and Well treatments, respectively. Total salt loads applied to pistachios would only be half of this if cotton had not been interplanted for the first two years as the cotton pulled substantial amounts of water from the pistachios. Net leaching from the pistachio rootzone is estimated at 5 to 20%.

The current trial is scheduled to run through 2008. Given sufficient funding, the pistachios will be monitored at least until 10 years of age (2014).

Conclusions and Practical Application

The final verdict is not yet in on the long-term viability of this project. In addition, only sites with sufficient drainage allowing a 15 to 25% leaching fraction will be suitable for this strategy. To this one grower, the eventual savings in annual water costs can exceed $200/acre for mature tree ET (45 inches/year). This equals $62,000/year for the 310 acre orchard. This doesn't even take into account the fact that planting this acreage would be impossible without using the "substandard" water. An economic analysis shows an estimated $1,779/ac net return above cash costs from the 3 years of cotton production (Table 3). .

At this writing there are about 15,000 additional acres of pistachios planted along the Westside since 2006 on ground that would not have been developed five years ago. Between marginal groundwater and blended drainwater there is more than 150,000 ac-ft/year of additional "alternative" water supply on the Westside that appears suitable for pistachios. Pistachio growers in Westlands Water District will be relying heavily on this water for 2008. The aggregate value of this water and the potential development of 30 to 40,000 acres of pistachios replacing cotton and wheat rotations could easily exceed a benefit of $30 million/year over the value of the field crops.

Table 3. Economic analysis of interplanted cotton irrigation costs and return for different water prices.

ANNUAL COSTS	DRIP $200/ac-ft	DRIP $120/ac-ft	DRIP $40/ac-ft
Water, 30 inches	*555.56*	*333.33*	*111.11*
Energy Cost	*41.67*	*41.67*	*41.67*
Irrigator	*13.89*	*13.89*	*13.89*
Quad Bike	2.00	2.00	2.00
Other cultural	450.00	450.00	450.00
Annualized Irrig System Capital Cost	*146.67*	*146.67*	*146.67*
TOTAL	***1209.78***	***987.56***	***765.33***

WELL TREATMENT	YIELD (lb/ac)	$/ac (Pima $1.10/lb)	Net $/ac ($200/ac-ft)	Net $/ac ($120/ac-ft)	Net $/ac ($40/ac-ft)
2004	2016	2218	1008	1230	1452
2005	999	1099	(111)	111	334
2006	1560	1716	506	728	951
	TOTAL	$5,033	$1,403	$2,070	$2,737
@ 65% OF TOTAL ACREAGE:			$912	$1,345	$1,779
20 year savings @ 5%:			*$2,420*	*$3,570*	*$4,719*
20 year water cost @ 40 in/year:			$13,333	$8,000	$2,667

Literature Cited

Ayars, J.E., R.B. Hutmacher, R.A. Schoneman, S.S. Vail, T. Pflaum. 1993. Long term use of saline water for irrigation. Irrigation Science 14(1):27-34.

Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. United Nations FAO Irrig & Drainage Paper No. 29, Rev.1.

Fardooel, A.R. 2001. Evaluation of salt and drought resistance of two pistachio species (Pistacia chinup and P. musica) in terms of growth and ecophysiological characteristics. Ph.D. dissertation. University of Ghent, Belgium.

Ferguson, L., B. Sanden, S. Grattan, 2003. Salinity tolerance of pistachio rootstocks. Annual Report, UC Salinity/Drainage Program Water Resources Center and Prosser Trust, 2002-2003, pp. 13-27.

Ferguson, L., P.A. Poss, S.R. Grattan, C.M. Grieve, D. Want, C. Wilson, T.J. Donovan and C. T. Chao. 2002. Pistachio rootstocks influence scion growth and ion relations under salinity and boron stress. J. Amer. Soc. Hort. Sci. 127(2):Pp.194-1999.

Fulton, A.E., J.D. Oster, B.R. Hanson, C.J. Phene, and D.A. Goldhamer. 1991. Reducing drainwater: Furrow vs. subsurface drip irrigation. California Agriculture 45(2):4-7, March/April 1991.

Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004. Effect of salinity on evapotranspiration and yield of San Joaquin Valley pistachios. Proceedings of the IVth International Symposium on Irrigation of Horticultural Crops, Acta Horticulturae 664:583-589.

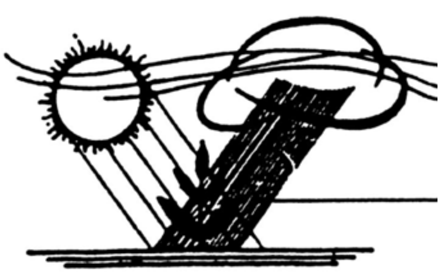
Shennan, C., S.R. Grattan, D. M. May, C. J. Hillhouse, D. P. Schactman, M. Wander, B. Roberts, S. Tafoya, R. G. Burau, and L. Zelinski. 1995. Feasibility of cyclic reuse of saline drainage in a tomato-cotton rotation. J. Environ. Qual. 24 (3):476-486.

Session III

Pest Management

Session Chair:

Tom Babb, CA Dept. of Pesticide Regulation



The Department of Pesticide Regulation's Environmental Justice Pilot Project

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Introduction

The California Environmental Protection Agency (Cal/EPA) is committed to integrating environmental justice (EJ) into its programs, policies, and actions. EJ refers to ensuring that the health and environment of *all* people are protected. It is defined in California statute as:

> The fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws and policies.

Cal/EPA's Environmental Justice Action Plan (Cal/EPA 2004) included six EJ pilot projects to be conducted by Cal/EPA boards and departments, with a focus on protecting children's health. The projects, begun in 2005, were planned as collaborative efforts within Cal/EPA and with communities, businesses, and other stakeholders. They were to explore ways to assess cumulative risks--local exposure and health or environmental effects from combined pollution emissions and discharges from all sources. They also were to seek opportunities to apply a precautionary approach by taking anticipatory action to protect public health and the environment if a reasonable threat of serious harm exists. While the projects focused on community-specific issues, the intent was to identify actions and strategies that would be applicable to other communities throughout the state.

The EJ pilot projects addressed issues as diverse as diesel and industrial emissions in southern California urban communities, cleanup and redevelopment in West Oakland, and establishment of a multistakeholder regional advisory group for reducing contamination of the New River (Calexico). DPR's was the only agricultural pilot project. In collaboration with the Cal/EPA Air Resources Board (ARB), DPR investigated children's exposure to pesticides in air in the low-income, predominantly Hispanic Fresno County agricultural community of Parlier (DPR 2005).

DPR EJ Pilot Project, Parlier, Fresno County

1. Goal

Evaluate ambient air exposure to pesticides in order to better understand and identify opportunities to reduce environmental health risk, particularly to children.

2. Procedures

DPR and ARB collected samples of ambient air at three Parlier primary schools throughout the 2006 calendar year. The samples were analyzed for 40 pesticides, including fumigants, insecticides, herbicides, and fungicides (Segawa, Wofford and Ando 2006). DPR scientists are evaluating the air monitoring data to determine whether the pesticides found in air pose a health concern, especially for children. The final project report, expected in late 2008 or early 2009, will contain an in-depth analysis of the Parlier air monitoring results and their significance.

A pest management assessment of the Parlier area's major crops—stone fruit (nectarines, peaches, plums), grapes, almonds, and citrus--was carried out as a complement to the air monitoring. The assessment highlights opportunities for DPR to take precautionary action by strengthening support for local pest managers who are interested in voluntary adoption of reduced-risk practices. It explains the local agricultural uses of soil fumigants and organophosphate insecticides (OPs) found in air, describes alternative practices already implemented by some growers, discusses research and outreach gaps, and lists new resources and potential partners for reduced-risk pest management initiatives (Matteson, Wilhoit and Robertson 2007).

3. Results and discussion

Parlier air monitoring data have been described in a series of progress reports (DPR 2006 a and b, 2007a and b). A total of 22 pesticides and breakdown products were detected. Soil fumigants and OPs were the agricultural pesticides detected most often (Table 1).

The OP diazinon was the only pesticide monitored that exceeded its DPR health screening level [1], for acute exposure on one day (Table 1). Preliminary analyses do not find specific pesticide exposures (and resulting risks) that require immediate regulatory action. However, DPR is initiating actions that could reduce and/or further evaluate the exposures.

The pest management assessment used Pesticide Use Report (PUR) data to analyze soil fumigant and OP use on major crops in the EJ Pilot Project area: the 152-sq-mile area (97,281 acres) within an approximate five-mile radius of the Parlier city limits. Stone fruit and grapes are grown most widely, on 44 and 42 percent, respectively, of acres planted in 2006. Citrus was grown on 4 percent of planted acres, and almonds on 2 percent.

1,3-D and chloropicrin are the most widely used soil fumigants in the project area, often applied in combination. They are used to kill soil pests and pathogens before orchards and vineyards are replanted. Figure 1 illustrates total pounds of AI applied in the project area 2002-06. These totals reflect the large acreages of stone fruit and grapes, as well as the frequency with which crop cultivars are changed.

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[1] Enforceable state or federal health standards have not been established for most pesticides in air. For the EJ Pilot Project, DPR and Cal/EPA's Office of Environmental Health Hazard Assessment developed acute (1-day) and chronic (two-week) health screening levels for each pesticide. By itself, a screening level does not indicate the presence or absence of a hazard, but detections above a screening level point to a need for further evaluation.

Table 1. DPR and ARB soil fumigant and organophosphate air sampling data with acute health screening levels, Parlier 2006.

Pesticide*	No. of Samples Collected	Percent of Samples with Detection	Highest 1-day Concentration (ng/m^3)	Acute Health Screening Level (ng/m^3)
Soil fumigants				
1,3-dichloropropene	71	34	23,082	160,000
MITC	468	84	5,010	66,000
methyl bromide	71	66	2,468	820,000
OPs				
chlorpyrifos	468	64	150	1,200
chlorpyrifos oxygen analog	468	22	28	1,200
diazinon	468	32	172	130
diazinon oxygen analog	468	19	71	130
phosmet	468	19	42	77,000
malathion	468	1	21	40,000
malathion oxygen analog	468	5	16	40,000

* The soil fumigant chloropicrin and the organophosphate methidathion were not monitored.
Source: DPR 2007b.

OP insecticides have broad-spectrum activity and are part of conventional pest management in every major crop in the project area. Only four were applied to any major crop within that area in an amount that exceeded 1,000 pounds of AI in a given year: chlorpyrifos, diazinon, methidathion, and phosmet. Figure 2 illustrates the 2002-06 average annual per acre use of those OPs in the project area, by crop.

Precautionary DPR initiatives to improve Parlier air quality

The EJ pilot project pest management assessment described research and outreach priorities for supporting voluntary reduction of soil fumigant and OP use in the project area.

Soil pest management in the Parlier area is particularly challenging because the sandy to sandy-loam soils worsen nematode problems while limiting some alternatives to soil fumigation. Replanting conventional commercial orchards and vineyards without fumigants normally involves 3-4 years of fallow and/or crop rotation, which is costly. The EJ Pilot Project pest management assessment identified the development of more and better alternatives to preplant soil fumigation as a priority for DPR and other stakeholders that support research to develop reduced-risk pest management practices.

In contrast, the assessment found that effective alternatives to OP application are already in use by some local growers to manage almost every key pest of the project area's major crops. Ongoing and new DPR projects are promoting and supporting the development and voluntary adoption of reduced-risk pest management practices and integrated pest management (IPM) systems that, among other benefits, minimize or eliminate OP use.

1. IPM for peaches and nectarines

In partnership with reduced-risk growers, the University of California (UC), the California Tree Fruit Agreement, and other stakeholders, DPR is implementing a 2004-08 U.S. EPA-funded project to demonstrate and promote peach and nectarine IPM practices, particularly among 53 large-scale growers around Parlier. The goal is to reduce the use of OPs and the broad-spectrum carbamate insecticide carbaryl by 20 percent. The project has produced a seasonal IPM decision guide that provides advice for every stage of the crop (Bentley et al. 2006).

2. Improved pesticide application technologies

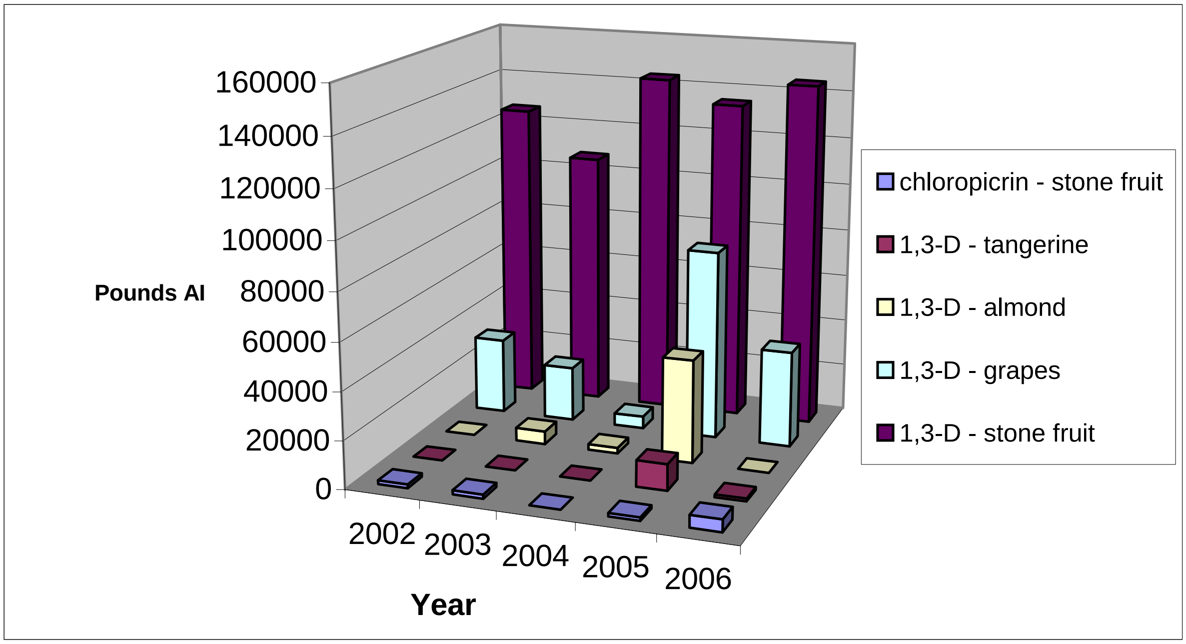
DPR's peach and nectarine IPM project is also promoting and developing pesticide application technologies that are more efficient and reduce exposure. The project helped the USDA Natural Resources Conservation Service initiate Environmental Quality Incentive Program (EQIP) co-payments to stone fruit growers who switch to target-sensing sprayers that reduce orchard pesticide use by 15-45 percent. NRCS then broadened its program to include other San Joaquin Valley crops. In 2007, those EQIP contracts covered 3,250 acres belonging to 12 stone fruit and row crop growers.

The project is also investigating remote sensing as a quick and potentially inexpensive way to monitor stone fruit orchards for mites. Preliminary results indicate that it may be possible to measure different levels of mite infestation via aircraft-based remote sensing. Linking this technology to geographic information system (GIS) and global positioning system (GPS)-guided variable-rate application equipment could enable growers to adjust miticide dosage and target applications within an orchard block on an as-needed basis, improving effectiveness and efficiency.

3. Vine mealybug research in grapes

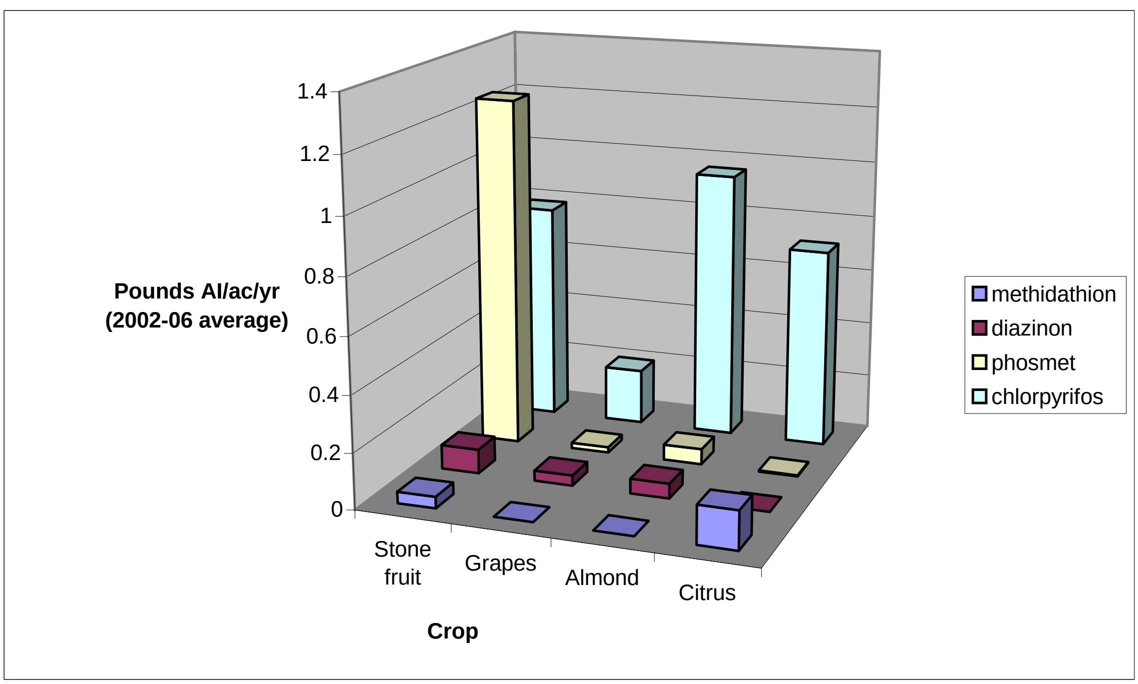
In May 2006, DPR awarded a two-year research contract to UC scientists Kent Daane and Walt Bentley for vine mealybug pesticide studies in the Parlier area. Until recently, the recommended insecticide program for this invasive vineyard pest relied on the OP chlorpyrifos. The project includes laboratory and field studies of the efficacy of novel pesticides (oils, soaps, insect growth regulators, neonicotinoids, botanical and/or bacterial insecticides) and their cost-effectiveness as part of a vine mealybug IPM system based on biological control and mating disruption with pheromones.

Figure 1. Total pounds of 1,3-D and chloropicrin used for major crops in the EJ Pilot Project area, Parlier, 2002-06.



The California Pesticide Use Report includes many soil fumigant applications that are simply labeled "preplant." This graph reflects only applications for which a crop was specified.

Figure 2. Per acre use of four OPs in major crops in the EJ Pilot Project area, Parlier, 2002-06 average.



Literature Cited

Bentley, W., C. Pickel, J. Hasey, R. Coviello, M. Viveros, B. Holtz, H. Andris, R. Duncan, M. Johnson, B. Ohlendorf, and G. Van Sickle. 2006. Seasonal Guide to Environmentally Responsible Pest Management Practices in Peaches and Nectarines. University of California Agriculture and Natural Resources Publication 21625. 8 pp.

Cal/EPA. 2004. Environmental Justice Action Plan. Sacramento: California Environmental Protection Agency. October. 12 pp.

DPR. 2005. Environmental Justice Pilot Project. Project Objectives, Pesticides, and Community for Monitoring. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. June. 29 pp. + Appendices A, B, C.

DPR. 2006a. Environmental Justice Pilot Project Pesticide Air Monitoring in Parlier. First Progress Report. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. June. 32 pp.

DPR. 2006b. Environmental Justice Pilot Project Pesticide Air Monitoring in Parlier. Second Progress Report. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. December. 18 pp. + 17 pp. figures, 25 pp. appendix.

DPR. 2007a. Environmental Justice Pilot Project Pesticide Air Monitoring in Parlier. Second Progress Report--Addendum. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. March. 10 pp. + 16 pp. appendix.

DPR. 2007b. Environmental Justice Pilot Project Pesticide Air Monitoring in Parlier. Addendum. ARB Monitoring Results. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. September. 9 pp.

Matteson, P., L. Wilhoit, and M. Robertson. 2007. Environmental Justice Pilot Project Pest Management Assessment: Soil Fumigant and Organophosphate Insecticide Use and Alternatives – Parlier, Fresno County, California. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation, Pest Management Analysis and Planning Program. Report PML-07-01, October. 45 pp.

Segawa, R., P. Wofford, and C. Ando. 2006. Environmental Justice Pilot Project Protocol for Pesticide Air Monitoring in Parlier. Sacramento: California Environmental Protection Agency, Department of Pesticide Regulation. December 30, 2005, revised March 1, 2006. 106 pp.

A Recently Introduced Pest: The Light Brown Apple Moth

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Introduction

The light brown apple moth (LBAM), *Epiphyas postvittana* (Walker) was discovered in California in 2007. Because of its known pest history in other countries, a great deal of concern occurred over its potential importance to California as a new pest. The following provides background information on the life history and biology of this insect, and the course of action underway to minimize its impact to California and a significant portion of North America where this insect could become established.

Pest Overview

The light brown apple moth is native to Australia. The genus *Epiphyas* consists of 40 species, all from Australia (Brown and Lewis 2004). Its potential host range includes over 120 plant species in more than 50 families (Geier and Briese 1981). A separate publication by Danthanarayana (1975) created a referenced-based listing of 27 plant families included as LBAM. It was noted that the families Compositae, Leguminosae, Polygonaceae and Rosaceae are among those most preferred, comprising 50% of the host plant species. Horticultural crops attacked by LBAM in Australia include pome, stone and citrus fruit and grapevines (Paull and Austin 2006).

In the past century it has invaded and become established in New Zealand, New Caledonia, the British Isles, and Hawaii (Danthanarayana 1975). In the southern region of Australia in the Territory of Victoria, LBAM commonly has three generations per year. This tortricid species is not known to diapause, responding to cold seasonal temperatures simply by a slowing of the rate of development. It passes the winter in the larval stage, completing development with moths emerging in mid-spring. These moths lay eggs in masses (approx. 30 per mass) on the upper leaf surface of smooth-leaved host plants for a subsequent generation leading to the next moth emergence in mid-summer (Danthanarayana 1975). During the summer, a generation can be completed in 4-6 weeks. From moths emerging in mid-summer arises another generation leading to a third moth flight in the fall that produces larvae that again pass through winter. In the warmest portions of its geographic range, LBAM has 4 generations per year, providing that suitable food is available throughout the year (MacLellan 1973, Buchanan et al. 1991). In the low elevation areas of Victoria, average peak summer and winter temperatures range from approximately 33/15^{o}C (91/59^{o}F) within the Territory's interior near Mildura to 26/13^{o}C (79/55^{o}F) approx. 385km (240mi.) to the south near the coastal city of Melbourne (source: Aust. Gov. Bureau of Meteorology-www.bom.gov.au). The average winter minimum temperatures in these locations are 4.3 and 5.3^{o}C respectively. In the mild climate of Tasmania only two generations occur (Evans 1937). The average summer/winter high temperatures in coastal and lowland regions of Tasmania are approx. 23^{o}C/12^{o}C (73/54^{o}F), and the average winter time minimum temperature is approximately 5^{o}C.

The light brown apple moth has been considered to be a sporadic pest of importance in south Victoria and Tasmania, where it damages apple, grape, lemon and other crops (MacLellan 1973). MacLellan (1973) suggested that its pest status had become elevated in these geographic areas, where it is a native species, due to the use of broad-spectrum insecticides. In recent discussions that the present authors had with Australian agricultural entomologists, LBAM was described as being a sporadic pest in southern mainland Australia; however, further south in the Territory of Tasmania it is regarded to be a very significant pest of several temperate climate crops. Recently, Sutherst (2000) put the annual cost of control and lost production in Australia at AU$21.1 million.

Moths are light brown with variable mottled light to dark brown patterns on the wings. Their bodies are approximately 7mm in length and when folded, the wings of males commonly exhibit a V-shaped boundary formed by a light colored anterior and darker posterior wing area. Adult longevity in Australia typically ranges from 2-3 weeks. In the presence of high quality hosts plants, adult moths are unlikely to disperse (Geier and Briese 1981). The preoviposition period ranges from 2-7 days in the field and oviposition can last upwards of 21 days, depending on temperatures. Females commonly lay 20 to 50 eggs per mass on the undersurface of leaves. The eggs overlap one another within a mass, resulting in a fish scale appearance. Egg production per female typically ranges from 120 to nearly 500 eggs although fecundity for a single female has been recorded to be as high as 1492. Danthanarayana (1975) also noted that a 1:1 moth sex ratio is typically observed in the field and in laboratory colonies. In contrast, Geier et al. (1978) discovered a sex ratio bias, favoring the production of female offspring. The basis for this was not known. Fecundity is highest at temperatures ranging from 20-25^{o}C (68-77^{o}F). Egg hatch occurs in approximately 7 days at temperatures above 20C. Larvae disperse upon hatching, commonly on to adjacent leaves to construct a shelter made of silk on the underside of leaves near the midrib. In subsequent instars (6 total), larvae construct nests by rolling leaves, webbing separate leaves together, or by making a silken nest within fruit clusters.

Numerous native parasitoids have been recorded to attack the light brown apple moth in Australia. These include egg, larval and pupal parasitoids (Paull and Austin 2006). In addition, various predatory insect and spiders can play an important role in LBAM population control (MacLellan 1973 and Danthanarayana 1983). These include lacewings, merids and spider species in the families Theridiidae, Thomisidae, Clubionidae, Salticidae and Araneidae.

Discovery of LBAM in California

The light brown apple moth was found in the San Francisco Bay Area of California in February of 2007. A survey was immediately implemented to determine its presence in the Bay Area counties and throughout the state, primarily with the use of sticky traps baited with a species specific pheromone lure. During the period from March to July of 2007, more than 34,000 traps were placed throughout the state to determine its distribution. The remaining report describes the survey results, and responses including eradication and biological control activities.

Surveys and nursery inspections

Delimitation surveys have identified a number of counties located near the San Francisco Bay area to have active populations of LBAM, including: Alameda, Contra Costa, Marin, Monterey, San Francisco, San Mateo, Santa Clara, Santa Cruz, and Solano. Encompassing approximately 800 sq. mi., this area is under quarantine and constant monitoring using 5 pheromone traps per square mile in urban environments and 1 trap per square mile in agricultural production areas. Monitoring is intensified within plant nurseries, using 1 trap per 5 acres. Outside of the region under quarantine, traps are located at sites where the gypsy moth and fruit flies are being monitored.

Eradication

Through a joint partnership between CDFA and USDA, an eradication effort was enacted that was primarily based on the use of mating disruption (i.e., the prevention of male moths from finding females). This included the use of a pheromone specific to the light brown apple moth, consisting of a 95:5 mixture of (E)-11-Tetradecenyl acetate: (E,E)-9, 11-Tetradecadienyl acetate.

An initial eradication response in early summer of 2007 occurred to the presence of LBAM in isolated areas outside the primary area of infestation. This response included the application of the microbial insecticide, Bt [*Bacillus thuringiensis*] coupled with the extensive use of LBAM pheromone to disrupt mating. The pheromone in use at this time was contained in plastic twist ties, requiring a large labor force to make the application. These were locations where very limited numbers of moths were caught, typically on one occasion.

For the principle area of infestation, insecticides were determined to be of limited value in providing a practical means of eradicating LBAM, therefore several other control techniques, including mating disruption, were considered for eradication. For mating disruption, the moth pheromone was broadly applied in ultra-low quantities contained in a commercially available carrier consisting of a biodegradable polyurea-based microcapsule suspended in water. Aerial applications of the pheromone were first made in the Monterey, Seaside area in September 2007, including an approximately 36 sq. mi. area. Due to limited availability of the complete pheromone, this application included only one component of the pheromone. An application was made to this same area in late October using the “full blend” comprised of both chemical components of the LBAM pheromone. In Early November, an aerial application was made in Santa Cruz and Salinas areas consisting of approximately 60 sq. mi. In buffer areas such as locations near waterways, the pheromone treatments were made by ground. The mating disruption technique is expected to be expanded to all affected areas in 2008. Methods for determining the success of this project include the monitoring of pheromone traps to determine if they are effective in luring in male moths, despite the disruptive presence of the large scale pheromone treatment. Also, a more definitive method involves the use of tethered virgin female moths, and the determination of whether or not they have mated over time.

Another potential means of eradicating LBAM includes the sterile insect technique. The sterile insect technique (also referred to as SIT) would include the mass rearing of millions of male moths that in turn are irradiated to cause sterility. These are mass released into the environment to compete with wild male moths for mating rights with female LBAM, thereby preventing wild female moths from ovipositing fertilized eggs. This approach will require several years for the development of large scale rearing facilities and efficient release methods.

Biological Control: Augmentation

Several native egg parasitoids in California in the family Trichogrammatidae are known to readily attack moth eggs (Pinto et al. 2002, Mansfield and Mills 2002, 2004). Two common species, *Trichgramma platneri* and *T. pretiosum* are commercially available in California. The potential for utilizing egg parasites to further decrease LBAM populations during implementation of the mating disruption project is being assessed. If native, commercially available *Trichogramma* spp. are determined to readily parasitize LBAM eggs, parasites may be released in concert with pheromone applications, thereby providing additional negative impact upon LBAM populations. Lab tests are underway to determine if these two species readily parasitize LBAM eggs.

Biological Control: Classical

Classical biological control includes the use of natural enemies obtained from the original geographic range of a pest for control of that organism within areas outside of its native range. New Zealand has been successful in benefiting in the control of the light brown apple moth through the introduction and establishment of several parasitoid species from southeast Australia where LBAM is native. A cooperative project between CDFA, UC-Berkeley and Australian scientists is underway to import several candidate species. In quarantine, they will be tested for host specificity and perhaps permitted for release.

References:

Brown, J.W. and Lewis, J.A. 2004. Catalogue of the type specimens of Tortricidae (Lepidoptera) in collection of the National Museum of Natural History, Smithsonian Institution, Washington, D.C. 510:1-60.

Buchanan, G.A., Stirrat, S.C. and Madge, D.G. 1991. Integrated control of light brown apple moth, *Epiphyas postvittana* (Walker), in vineyards. Wine Industry Journal 6:220-222.

Danthanarayana, W. 1975. The bionomics, distribution and host range of the light brown apple moth, *Epiphyas postvittana* (Walk.)(Tortricidae). Australian Journal of Zoology. 23:419-437.

Danthanarayana, W. 1983. Population ecology of the light brown apple moth, *Epiphyas postvittana* (Lepidoptera: Tortricidae). J. An. Ecol. 52:1-33.

Evans, J.W. 1937. The light-brown apple moth (*Tortrix postvittana*, Walk). The Tasmanian Journal of Agriculture 8: 1-18.

Geier, P., Briese, D. and Lewis, T. 1978. The light-brown apple moth, *Epiphyas postvittana* (Walker) 2.Uneven sex ratios and a condition contributing to them in the field. Australian Journal of Ecology. 3:467-488.

Geier, P. and Briese, D. 1981. The light-brown apple moth, *Epiphyas postvittana* (Walker): a native leafroller fostered by European settlement. Pp.131-155. *In* R. Kitching and R. Jones [eds.], The Ecology of Pests. CSIRO, Melbourne, Australia.

MacLellan, C. 1973. Natural enemies of the light brown apple moth, *Epiphyas postvittana*, in the Australian Capital Territory. Can. Entomol. 105:681-700.

Mansfield, S. and Mills, N.J. 2002. Host egg characterizatics, physiological host range, and parasitism following inundative releases of *Trichogramma platneri* (Hymenoptera: Trichogrammatidae) in walnut orchards. Environ. Entomol. 31:723-731.

Mansfield, S. and Mills, N.J. 2002. A comparison of methodologies for the assessment of hot preference of the gregarious egg parasitoid *Trichogramma platneri*. Bio. Control 29:332-340.

Paull, C. and Austin, A.D. 2006. The hymenopteran parasitoids of light brown apple moth, Epiphyas postvittana (Walker) (Lepidoptera: Tortricidae) in Australia. Aust. J. of Entomol. 45:142-156.

Pinto, J.D., Koopmanschap, A.B., Platner, G.R., and Stouthamer, R. 2002. The North American *Tichogramma* (Hymenoptera: Trichogrammatidae) parasitizing certain Tortricidae

(Lepidoptera) on apple and pear, with ITS2 DNA characterizations and description of a new species. Biol. Control 23:134-142.

Sutherst, R.W. 2000. Pests and Pest Management - Impact of climate change. Rural Industries Research and Development Corporation. Publication No. 00/16, Project No. CSE-76A. 34pp.

Managing Diaprepes Root Weevil, a Polyphagous Pest

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Introduction

Diaprepes root weevil (*Diaprepes abbreviatus* (L.); Coleoptera: Curculionidae), native to the Caribbean, is a serious insect pest of crops and ornamental plants everywhere it is established (Woodruff 1964, 1968). Its extreme pest status is derived from its polyphagous habit and its life cycle. This weevil will feed on or is associated with over 290 species of plants in 59 plant families (Simpson et al. 1996, 2000). Many of these plants are agronomic crops or interior or exterior ornamental plants. Once introduced into an area, Diaprepes root weevil can utilize a variety of plants, thereby increasing the likelihood of establishment after introduction.

The habits and life cycle of Diaprepes root weevil also contribute to its pest status. The adult weevils are most active from dusk through dawn and hide in the foliage during the day. Thus, they are rarely seen until their population densities attain a moderately high level. Diaprepes larvae and pupae are typically not observed because these stages are completed below the soil surface. For some hosts, no above-ground symptoms will be evident on the host plants until larval densities are high (Knapp et al. 2000).

Life Cycle of Diaprepes

Diaprepes root weevil has a long life cycle with much of it spent below the soil's surface. The adults are long-lived, surviving for approximately 135 – 147 days (Beaver 1982). The adults mate shortly after emerging from the pupal chamber, and females begin to oviposit about 7-14 days after mating (Wolcott 1936, Beavers 1982). Female weevils may lay between 5,000 – 6,500 eggs in their life time (Wolcott 1936, Beavers 1982). The eggs are placed in a single layer in clusters of 25-250 eggs, and sandwiched between two leaves or edges of a leaf (Woodruff 1968). The female weevil secretes a gelatinous substance to hold the leaves together (Woodruff 1968).

The young larvae hatch from the eggs in about 7 – 10 days, and drop to the soil surface (Beavers 1982). They move about on the soil surface for several days before burrowing into the soil (Woodruff 1968). The larvae initially feed on small, feeder roots, but progress to larger roots or other underground plant structures as they mature (Woodruff 1968). This feeding activity removes root tissue and opens up the roots to infection by root rot pathogens. The larvae complete 10 or 11 instars in 6-18 months (Woodruff 1968, Quintela et al. 1998). The mature larvae (instar 10 or 11) construct a chamber in the soil in which to pupate. The pupal stage lasts from 15 to 30 days (Woodruff 1968). Adult weevils will emerge from the pupal stage, but will not emerge from the pupal chamber in the soil until the soil has appropriate soil moisture (McCoy et al. 2003).

Diaprepes root weevil adults do not travel far from their emergence spot or leave host plants unless food resources are depleted or they are disturbed. When disturbed, they feign death and fall to the ground. They then walk back to the trunk or stem of the nearest plant, and return to the canopy (Woodruff 1968). Because of these behaviors, natural dispersal of the weevil is slow. Their more rapid dispersal is due to the movement by man of plants and other plant-related materials infested with Diaprepes.

California Infestations

Diaprepes root weevil was first found in a citrus nursery in Apopka, Florida, in 1964 (Woodruff 1964). Since that time, the weevil has spread to 22 counties in Florida (Hall 2000). In 2001, Diaprepes adults were found in a citrus grove in the Rio Grande Valley near McAllen, Texas (Skaria and French 2001). Despite removal of the grove, a small area in the Rio Grande Valley is considered infested with Diaprepes root weevil. There have been numerous interceptions of Diaprepes in California in plant material, trucks, trailers, and cargo holds of aircraft since 1974. The weevils found in these interceptions were destroyed. However, on September 14, 2005, a Diaprepes adult was found in a gypsy moth trap that had been placed in Newport Beach (Orange County). Follow-up surveys of the area revealed that the infestation was located in two adjacent neighborhoods. On October 10, 2005, Diaprepes root weevil was reported from Long Beach (Los Angeles County). The infestation in this area was comprised of one neighborhood. On April 28, 2006, Diaprepes root weevil was first found in La Jolla (San Diego County). As of October 17,2007, there were six quarantine areas in San Diego County (approximately 32 sq. miles), four quarantine areas in Orange County (approximately 9.6 sq. miles), and two quarantine areas in Los Angeles County (approximately 3.5 sq. miles). All of the areas have been placed under eradication programs.

Management of Diaprepes Root Weevil

Current management programs for Diaprepes root weevil have eradication as the objective. The programs rely on regulations to limit the spread of the weevil and on chemical control to reduce the density of the above-ground life stages, eggs and adults. Research is also being conducted on biological and cultural control methods that may be integrated into the eradication programs or used in cross-commodity, area-wide management programs for Diaprepes, should such programs become necessary.

Eradication programs for Diaprepes are implemented within the boundaries of the quarantine area, defined as all areas within 656 ft (200 m) of an infested property. Within the quarantine area, the movement of plants, soil, and other plant related materials and the production and sale of plants are regulated. These regulations, when followed, will limit the spread of Diaprepes out of an area and allow for Diaprepes-free plants to be produced and sold. Insecticidal treatments targeting adults and eggs are being applied to all known infested properties, up to 164 ft (50 m) from infested sites. Because of the mosaic of habitats within the quarantine areas, a number of different insecticides are being used. Entomopathogenic nematodes and egg parasitoids are also being investigated as to their efficacy and appropriateness for use in the eradication program.

Literature Cited

Beavers, J. 1982. Biology of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) reared on artificial diet. Florida Entomol. 65: 263-239.

Hall, D. 2000. History and importance of Diaprepes to Florida. Futch, S. (Ed.). Diaprepes short course. Citrus Res. Ed. Foundation, Inc., Lake Alfred, Florida. pp. 13-18.

Knapp, J., Simpson, S., Pena, J. and Nigg, H. 2000. Diaprepes root weevil: what Floridians need to know. ENY-640. http://edis.ifas.ufl.edu.

McCoy, C., Stuart, R., and Nigg, H. 2003. Seasonal life stage abundance of *Diaprepes abbreviatus* in irrigated and non-irrigated citrus plantings in central Florida. Florida Entomol. 86: 34-42.

Qunitela, E., Fan, J., and McCoy, C. 1998. Development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) on artificial and citrus root substrates. J. Econ. Entomol. 91: 1173-1179.

Simpson, S., Nigg, H., and Knapp, L. 2000. Host plants of Diaprepes root weevil and their implications to the regulatory process. In Futch, S. (Ed.). Diaprepes short course. Citrus Res. Ed. Foundation, Inc. Lake Alfred, Florida. pp. 19-37.

Simpson, S., Nigg, H., Coile, N. and Adair, R. 1996. *Diaprepes abbreviatus* (Coleoptera: Curculionidae): host plant associations. Environ. Entomol. 25: 333-349.

Skaria, M. and French, J. 2001. *Phytophthora* disease of citrus associated with root weevils in Texas. Phytopathology 91: Suppl. S203.

Wolcott, G. 1936. The life history of *Diaprepes abbreviatus* L. J. Agric., Univ. of Puerto Rico 20: 883-914.

Woodruff, R. 1964. A Puerto Rican weevil new to the United States (Coleoptera: Curculionidae). Florida Dept. Agric. Div. Plant Indus. Entomol. Circ. 30: 1-2.

Woodruff, R. 1968. The present status of a West Indian weevil (*Diaprepes abbreviatus* L.) in Florida (Coleoptera: Curculionidae). Florida Dept. Agric. Div. Plant Indus. Entomol. Cir. No. 77.

Third Party Certification for Pest Management Practices

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Introduction

The concept of "sustainability" has been discussed in agriculture for decades but recently has penetrated the American consumer market as never before. Organic agriculture can be considered the "mother" of food certification, but today several other non-organic third-party certification programs are in existence or are being actively considered by growers, retailers, food service companies, government agencies, and environmental organizations. Some of the names are familiar to many in the industry, others less so – EurepGAP, Wal-Mart, SYSCO, Food Alliance, Protected Harvest, Lodi Rules!, Rainforest Alliance, and Scientific Certification Systems. This presentation will provide an overview of selected past and current sustainable agriculture certification systems and some recent developments.

Historical programs

The organic agriculture movement has its roots in the 1930's and 40's, but third-party certification developed in the 1970's and beyond. The US industry became regulated in 2002 with the implementation of the National Organic Program legislation. In the meantime, several other efforts at voluntary certifications outside of the organic realm developed in the 1990's and the new century.

Internationally, the Rainforest Alliance started in 1987 to address concerns that products from the tropics be produced in a way that did not deplete rainforests.

The University of Massachusetts developed a "Partners with Nature" program around IPM in the mid 1990's. Shortly thereafter, Wegman's supermarket chain and Cornell University in New York developed an " IPM Certified" brand for vegetables sold by Wegman's. Other similar efforts followed, primarily on a small-scale in the NorthEast US. Few, if any of these initial domestic efforts succeeded.

Unless otherwise stated, the programs mentioned here include an inspection and/or audit of the operation in question to verify that the practices reported by the grower were in fact implemented.

Current major players

<u>Food Alliance</u>

The Food Alliance is a non-profit organization which started in the Northwest US in the mid-1990s and continues today with offices in Oregon, Minnesota, and a new office in California. There are 2 parts to the Food Alliance certification – a whole farm standard, which contains general requirements which apply to every certified farm, and a product-specific standard, of which there are 55 for the Northwest and fewer for the Midwest, which addresses the requirement of a particular crop. Both parts of certification must be passed by a grower to sell a product as Food Alliance certified. Each topic addressed in the standard (whether whole farm or product-specific) has 4 options, with 1 to 4 points gained for whichever category the operation falls into. The product-specific standards were developed by a consultant and reviewed by a panel of stakeholders. The Consumer's Union has criticized the program for not including broad public and industry (grower) input (http://eco-labels.org accessed December 20, 2007).

A grower must implement practices which have a total point value of at least 75% of points in each standard (whole farm and product). Food Alliance certification covers pest management and some other resource concerns such as soil and water management. Social issues related to labor are also included. Food Alliance additionally requires that their growers not use genetically modified organisms, has a list of prohibited pesticides, and does not permit the use of hormones or antibiotics for livestock operations. Food Alliance reports over 270 certified farms managing over 4 million acres, but admits that the majority of these acres are grasslands. Most of the certified operations are in Oregon; as of December 2007 there were 3 in California.

Protected Harvest

Protected Harvest was founded in 2001 as an outgrowth of an alliance of the University of Wisconsin, the Wisconsin Potato and Vegetable Growers Association, and the World Wildlife Fund. This alliance had developed a pest management program for potatoes which lowered pesticide use dramatically and protected wildlife. A marketing program was developed and a third-party certifier was desired to add credibility. An independent non-profit organization was developed with a board drawn from agriculture, environmental organizations, and marketing specialists. Protected Harvest continues to certify this potato program today. A second certification program to apply for approval and annual certification by Protected Harvest was the Lodi Rules! program of the Lodi Woodbridge Winegrape Commission, now in its third year of certification.

In addition to these 2 programs, Protected Harvest facilitates the development of certification standards. By policy, all standards must be developed collaboratively by growers and experts in the crop in question, be peer reviewed, be transparent (available online for public review and comment), be crop and region-specific (to address local environmental and pest management concerns), and be reviewed and approved by the inter-disciplinary Protected Harvest board. While this approach has been favorably received by Consumers Union, it also is more time consuming and expensive and has limited the growth of Protected Harvest. As of December 2007 Protected Harvest was actively certifying potatoes in Wisconsin, winegrapes and wine in California, stonefruit in California, mushrooms in Pennsylvania and California, and was making preparations to certify citrus in California.

Protected Harvest standards cover pest management, soil and water management and air quality. Social issues are not covered explicitly, though some standards address some labor issues. Each program's requirements are set by the collaborative committee which establishes the standards, but generally the requirement is that 70% of points available be achieved for certification. An additional component of the Protected Harvest certification is a Pesticide Environmental Assessment System by which all pesticide applications for the season are scored with a numeric ranking system of the relative impact on the environment (birds, bees, water organisms, workers, and consumers). The growers are given a budget (also established by the committee) for the year and must maintain their total impact score within the budget in order to be certified.

SYSCO

SYSCO is the largest food-service company in the US (Bosner 2007), distributing fresh and prepared food items to restaurants, nursing homes, schools, colleges, industrial campuses, cruise ships, etc. In 2005, SYSCO initiated an expansion of its quality assurance program to look beyond food safety and quality to sustainable agriculture. A set of standards addressing sustainable agriculture, IPM, and related environmental issues were developed and distributed to the processors. The standards addressed both the processing facility and supplier farms, and a good deal of flexibility was built in. As of 2006, all suppliers of processed foods to SYSCO were required to be audited against the standards by a third party inspection company. Processors whose audits revealed substandard performance are required to demonstrate improvement within a set timeframe or lose their contract with SYSCO.

EurepGAP

EurepGAP is a standard of "good agricultural practices" established by a consortium of European retailers in 1997 which includes some environmental practices. The retailers wanted to address a growing concern for safety, the environment, and labor, according to the EurepGAP website. Agricultural suppliers exporting to these retailers must undergo an audit against the standards. Americans often assume that EurepGAP is an EU or other government standard, but it in fact has had no significant government input or attention.

Recent developments

Corporate trends

Many corporations are beginning to consider and implement sustainability programs, including Wal-Mart and McDonalds. This is being driven in part by a new interest of investors in "corporate social responsibility" reporting on issues related to labor and the environment. Other drivers include a concern about global warming and greenhouse gasses (as exemplified by Al Gore's Nobel Prize and Academy Award) and consumer awareness driven media such as Michael Pollan's bestselling book *The Omnivore's Dilemma: a natural history of four meals* and related columns in the New York Times.

A potential national standard

In 2007, Scientific Certification Systems (SCS), a for-profit certification company with extensive experience with food safety audits, pesticide residue laboratory tests, and retailer environmental sustainability efforts, filed a draft "National Sustainable Agriculture" standard with the American National Standards Institute (ANSI), a national body that approves industry standards for such things as telecommunication equipment and myriad other industrial products and processes. By filing this draft standard, SCS has initiated a process that will take up to 3-years to solicit public and industry input into the draft through a committee process and produce a standard that has at least majority approval from the committee. The committee will be formed in early 2008.

Literature Cited

Anonymous. 2008. Consumers' Union Greener Choices website. (available http://eco-labels.org).

Anonymous. 2008. EurepGAP website. (available http://www.eurepgap.org).

Bosner, U. 2007. Every Bite You Take: How SYSCO came to monopolize most of what you eat. Slate. (available http://www.slate.com/id/2160284/).

Dlott, J., Gunders, D. and Arnold, A. 2006. Sustainability Trends in the Food Sector: a SureHarvest briefing paper. SureHarvest, Soquel, CA. (available: http://www.sureharvest.com/pdf/SureHarvest-SustainabilityTrends.pdf).

IPM Certification and Labeling

Weinzierl, R. 1998. IPM Certification and Labeling. Agrichemical and Environmental News, October 1998. Washington State University, Pullman, WA.

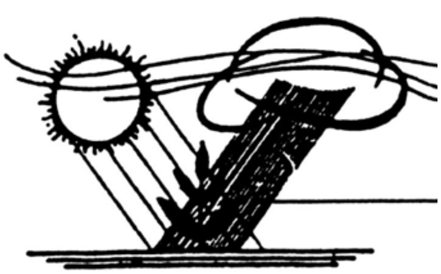
Session IV

Maintaining Soil Resources

Session Chairs:

Suduan Gao, USDA-ARS

Rob Mikklesen, IPNI



Sustaining Soil, Sustaining Society

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Introduction

The challenge for soil scientists and agronomists is enormous. I illustrate the nature of the challenge with three quotes from the Nobel lecture given by Nobel Peace Prize recipient Norman Borlaug in 1970:

> "Civilization as it is known today could not have evolved, nor can it survive, without an adequate food supply."
>
> "Almost certainly, however, the first essential component of social justice is adequate food for all mankind. Food is the moral right of all who are born into this world."
>
> "There are no miracles in food production."

Providing this food and maintaining the soil resource is a major responsibility of the soil scientist and the agronomist. Population is growing rapidly, especially in less economically developed parts of the world, but the area of soil available for food and fiber production does not change appreciably. Misuse of soil reduces its value for production and forces us to use soils that are less suitable for intensive production. Is this sustainable? What are the land-conserving technologies that have helped stave off the Malthusian prediction of societal collapse and mass starvation? How have these technologies impacted soils and how should we address these impacts? How can we as soil scientists and agronomists answer the challenge presented by 800 million starving and 2 billion hungry people in the world?

Addressing the Questions

Sustainability

Sustainability has been defined in many ways, all of which may be correct, depending on one's point of view. For a soil scientist, a sustainable agricultural system is one that maintains or improves its capacity to produce food and fiber. This can be translated into returning the nutrients removed from the soil through harvest, maintaining the soil physical properties and managing the unintended consequences of intensive agriculture. How is this best accomplished?

Land Conserving Technology

A land conserving technology is one that increases production per unit of soil area. Without land conserving technologies, more land is needed to produce the same amount of food and fiber. Without land-conserving technologies, shallow soils, soils on steeply sloping landscapes, soils with chemical imbalances and soils supporting pristine ecosystems are used for production. Using these lands for cultivated agriculture normally has negative ecological consequences. How can the best lands for agriculture be reserved for that use?

Technology and Soil Management

Many technologies have increased production but stressed the soil. Least well managed are the physical properties of soil, especially density, porosity and aggregation that control soil hydrology. For example, substituting very large tractors for small ones has the potential to increase soil density, decrease porosity and force a change in water management. Soil chemistry is typically well managed but new challenges are ahead. Use of soils for waste disposal, for example, has the potential to add new and unwanted chemicals to the soil, changing its production value. Demand for crop-based fuel to supplement petroleum will put new demands on soil that will change fertility and organic matter management. How will we best meet these new challenges?

Conclusions

Soils are ubiquitous but little understood or appreciated by the vast majority of humanity. The challenges for soil scientists are great because the Malthusian problem of rapidly increasing population and static soil resources continues. Our responsibilities as soil scientists are to feed the world and preserve and protect the soil resource, through wise management and education. Are we up to the task?

Salt Management: A Key To Irrigation Sustainability In Arid Climates

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Abstract

Salt management is a critical component of irrigated agriculture in arid regions like the Westside San Joaquin Valley (WSJV). This requires sustaining acceptable level of salinity in the crop root zone, subsurface drainage and a location to dispose drainage water, particularly, the salts it contains, which degrade the quality of receiving water bodies. Despite these needs, irrigation in the WSJV was started with insufficient attention to sustainable re-use or disposal of saline drainage water, and to salt disposal in general. Now, the costs of regional collection of the drainage water and its disposal into San Joaquin Delta, or the San Francisco Bay, or the Pacific Ocean are extraordinarily high; the same is true for in-valley disposal, involving drainage water reuse to reduce drainage volume and Se removal to facilitate drainage disposal into evaporation basins.

In response to water quality mandates by regional and state water quality control boards, irrigation districts north of Mendota have begun implementing irrigation and crop management practices that reduce drainage volumes. In response to court decisions that reduce water deliveries, and to the high cost of salt disposal, irrigated lands along the valley trough are being removed from irrigation. Groundwater use for irrigation will increase, and consequently so will salt disposal into the underlying soil strata and groundwater, the disposal locations in place since irrigation with groundwater began in the WSJV. The combination of land retirement and increased use of groundwater water for irrigation will likely reduce the area impacted by high water tables. It may be possible to maintain water tables at acceptable depths with improved irrigation, reuse of drainage water for irrigation, and increased groundwater use for irrigation. However, all of salt would then be disposed in underlying soil strata and the groundwater. If this mode of salt disposal were acceptable, or remains unregulated, it could motivate water delivery agencies and water users to seek efficient methods for reducing the amount of salt needing disposal and to develop water management strategies to facilitate salt disposal in ways that are affordable and environmentally acceptable.

Challenges On Salinity Management In Irrigated Agriculture in California

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California has a long history of salinity and drainage problems (Tanji, 2000). Salinity, and particular ionic constituents in the irrigation or drainage water, has adversely impacted crop production to some degree in virtually every County in the state. Some impacts have been very dramatic while others may be mild or likely undetected.

On a global perspective, California's salinity problems are minor in comparison to the challenges facing countries whose food and fiber supply rely on a very scare supply of water. Middle eastern countries such as Jordan, Israel, Egypt, Syria, Iraq, Iran, Saudi Arabia and the gulf countries all face major water shortages and salinity problems. The same goes for vast areas of India, China, and North Africa. Even countries such as Australia and Chile face major salinity issues. While California faces salinity and water shortage problems, most other countries facing such problems would trade places with California in a heart beat.

Nevertheless, salinity does impact California production and causes losses of millions of dollars annually. Because of California's diversity in agricultural crops, climates, watersheds, and water management practices, how salinity impacts crop production differs from one place to another.

In the western San Joaquin valley, the threat of salinity is from high saline water tables and inadequate drainage (SVDP, 1990). The composition of this shallow saline water is dominated by sodium sulfate but there are large concentrations of Cl, HCO_3, Ca and Mg as well. Growers are still unable to dispose of agriculture drainage water to the bay-delta or any other saline sink. Therefore strategies to reduce drainage volumes such as reuse and source control have been a popular method of at least minimizing or postponing the inevitable drainage treatment and disposal option.

In the Imperial and Coachella valleys, drainage water is discharged into the Salton sea, keeping the sea level from residing as fast as it would otherwise, but concentrations of salt, Se and other constituents continue to concentrate. Because the evaporative powers of the sun in this arid environment, salts and constituents will continue to increase and eventually concentrations will reach that of the Dead sea between Israel and Jordan (concentrations reaching 100X sea water). Regardless of interventions, no economic solution to battle the suns evapoconcentration effect is currently possible.

In Coastal valleys of California including Salinas, Monterrey, Santa Maria, Lompoc, Ventura and Oxnard, salinity in many wells have increased over time due to the combination of overdraft and seawater intrusion. Many of the salts in these aquifers are dominated by sulfate but the composition is steadily changing in favor of Cl salts from the sea. Although cool season vegetables continue to flourish in the area, salinity is likely reducing the yield potential in some areas. More obvious is isolated cases of salinity effects on very salt sensitive species such strawberry and avocado.

The bay-delta is also threatened by salinity, which is dependent upon the tide and river flows. High tides and low stream flows can increase the salinity of the delta where salinity decreases with distance from the bay. This increased salinity can have an adverse effect on crops, particularly salt sensitive crops grown in the Sacramento-San Joaquin delta.

Recycled municipal waste water is becoming more and more attractive as a water source for irrigation of landscapes and agricultural crops. Many cities and using the water to irrigate golf courses, parks and other city maintained landscapes. In these instances, salinities affect on the aesthetic quality of the landscape is of paramount importance. Waste water is also used extensively in southern California and northern California to grow crops including vineyards (Webb, 2006). Increased use of recycled water will most certainly continue to increase and expand to other crops and other landscape settings.

Salinity can also be problematic in areas one would never consider to be a salinity threat. Examples include rice production in the Sacramento valley or wild rice production in northeastern California. In some areas in the Sacramento valley, some of the irrigation water in districts are recycled and growers on the lower end use water of poorer quality than those at the upper end. When seemly good quality water is evapoconcentrated as is moves from check to check, salinity can increase in lower basins to a level that will reduce grain yields of this salt-sensitive crop (Scardaci et al., 2002). In Northeastern California, isolated saline seeps can affect wild rice production (Marcum, 2006).

What will the future hold? Salinity in California's agriculture, although not as severe in many arid parts of the world, is still a threat to production and will have to carefully managed in the future. There will be an increasing demand for good quality water and annual supplies many not be as dependable as they have in the past. Increased amounts of stream water are needed to protect threatened aquatic species. Moreover, with global warming becoming a reality, snow pack in the Sierra Nevada mountains, the primary source of irrigation water in the Central Valley, will be dwindling. Snow levels are gradually advancing to higher elevations over the years meaning that a continuous supply of river water to reservoirs will be decreasing. Therefore salinity will always be a problem in irrigated agriculture in California. What the future holds is for academics, state, federal and local agencies, and policy makers to better understand the problems, understand where and how they occur, and how to best manage the problem to minimize the adverse effects and all potentially users.

References

Marcum, D.B. 2006. Salinity survey for wild rice. 2006. Shasta Lassen Cooperative Extension.

San Joaquin Valley Drainage Program (SJVDP). 1990. A management plan for agricultural subsurface drainage and related problems on the Westside San Joaquin Valley. Final report of the San Joaquin Valley Drainage Program. U.S. Dept. Interior and Calif. Resources Agency, 183pp.

Scardaci, S.C., M.C. Shannon, S.R. Grattan, A.U. Eke, S.R. Roberts, S. Goldman-Smith and J.E. Hill. 2002. Water management practices can affect salinity in rice fields. Calif. Agric. 56(6):184-188.

Tanji, K.K . 1990. *Agricultural Salinity Assessment and Management*: Manuals and Reports on Engineering Practice No. 71 Am. Soc. Civil Eng. New York, pp 432-449.

Webb, E. S. Grattan, B. Hanson, R. Meyer, T. Prichard and L. Schwankl. 2006. Evaluation of Napa Sanitation District recycled water quality for vineyard irrigation. Report submitted to the Napa Sanitation District. January 2006

The Role of Private Land Trusts in Maintaining Soil Resources

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Introduction

Sequoia Riverlands Trust (SRT) is a private, non-profit conservation organization – a land trust – dedicated to conserving the natural and agricultural legacy of the southern Sierra foothills and southern San Joaquin Valley. SRT carries out its mission by working with willing landowners to acquire interests in priority properties, as well as through land stewardship, education, and participation in area land use planning efforts.

SRT is helping to maintain soil resources by:

- putting lands into various kinds of "conservation ownership" that prevent permanent conversion to residential or industrial uses
- actively managing SRT-owned lands
- restoring degraded lands
- providing outdoor learning opportunities to raise awareness of the importance of living soils and other natural systems to the well-being of humans

Examples of each of these strategies are described below.

Putting Lands in "Conservation Ownership"

Conservation easements are the primary mechanism used by SRT and other land trusts to conserve lands. A conservation easement is a legal agreement between a landowner and a qualified organization whereby the landowner voluntarily restricts the future uses of a property to permanently protect rangeland, farmland, scenic open space, wildlife habitat or other desired values. Typically, a conservation easement limits subdivision, construction of homes and associated improvements, and non-agricultural commercial uses. The landowner retains the underlying title (i.e. all rights not explicitly restricted by the easement), and may sell the property. However, the easement document is attached to the property's deed and recorded with the county, so easement terms apply to all future landowners.

Landowners may sell or donate a conservation easement to an organization like SRT. The value of the conservation easement is the difference between the appraised value of the property without any restrictions, and the value with the conservation easement in place. The donated value of the conservation easement is considered a charitable donation by the IRS, and can result in substantial tax benefits (income and estate taxes primarily, sometimes property taxes). For landowners who are "land rich and cash poor", the charitable deductions associated with conservation easements can be an important estate planning tool.

Sequoia Riverlands Trust currently holds fifteen conservation easements protecting 2,594 acres of rangeland, open space and wildlife habitat. SRT is embarking on a major farmland preservation effort, initially focused on mitigation of development impacts to farmland in Kern County.

Actively Managing SRT-owned Lands

SRT currently owns 4,566 acres outright, distributed among seven preserves in Tulare County. These "fee title" lands protect excellent examples of the area's unique habitats, such as valley oak woodland, vernal pool grasslands, and foothill blue oak woodlands. SRT actively manages its preserves, including livestock grazing leases, range improvements, weed management and visitor access.

The 1,820 acre Homer Ranch property north of Lemon Cove is a success story for maintaining soil resources through improved management practices. When SRT acquired the property in 2004, existing range improvements were in poor shape, grazing rights were subleased to an absentee operator, and cattle camped out along the creek bottom much of the year. The results were poor forage utilization, trampled creek banks, skinny cows and unhappy neighbors.

Two years ago SRT selected a new team of grazing lessees through a competitive process. Selection criteria included past involvement in range improvement or restoration projects. Since then, the grazing lessees, SRT, the Natural Resources Conservation Service (EQIP & WHIP programs) and U.S. Fish and Wildlife Service (Partners program) have teamed up to construct or rehabilitate several miles of fencing, three spring developments, a pond and a major well-based stock watering system. Fencing included 2.5 miles along Dry Creek, enabling regulation of cattle use in the creek bottom for both stream bank protection and a riparian management study funded by The Nature Conservancy. The grazing lessees have taken pains to move cattle among the three major pastures in response to changing forage conditions, and have selected cattle that work the rugged country. As a result, grazing intensity is now moderate throughout the ranch, stream bank trampling is much reduced, and riparian under-story vegetation is returning to the creek bottom.

Restoring Degraded Lands

SRT has chosen to put land restoration at the forefront of its stewardship program. Substantial restoration projects are under way at three preserves, in partnership with NRCS, the U.S. Bureau of Reclamation (CVPIA Habitat Restoration Program), the California Wildlife Conservation Board, the U.S. Fish & Wildlife Service, an anonymous private foundation, grazing lessees and a number of other donors and volunteers.

SRT's most ambitious project has been the restoration of Dry Creek Quarry, a retired aggregate mine donated to the land trust in early 2004. Virtually the entire 152-acre site was modified by ten years of mining, including excavation, spoils dumping, streambed alterations, and construction of roads and processing facilities. Through private foundation and NRCS-WHIP grants, in-kind donations and hundreds of hours of volunteer labor, SRT has completed restoration of about 80% of the site. The major thrust of the project has been to restore braided streams flows and natural patterns of flooding and deposition; return disturbed uplands to more natural contours; stabilize slopes with native plantings; and restore the unique sycamore alluvial woodland along Dry Creek. To support the restoration SRT also established an on-site native plant nursery that is becoming an important source of local, native plant materials for restoration and landscaping projects in the region.

In the coming year SRT and the Kaweah Delta Water Conservation District intend to collaborate on reclamation of the remaining 20% of the site, a water-filled hard rock pit with excellent wetland habitat potential.

SRT plans to actively share the lessons of the Dry Creek Quarry project, the first mine reclamation in Tulare County.

Providing Outdoor Learning Opportunities

SRT currently hosts an elementary school field trip program at the Kaweah Oaks Preserve, serving about 1,000 children per year. The curriculum includes soil and water conservation, and lessons on how soil and other natural systems support food production and other human needs.

Similar messages find their way into SRT's monthly public walks, publications and presentations.

Summary

Sequoia Riverlands Trust and other land trusts play a significant role in maintaining soil resources through conservation easements, land acquisition, stewardship, restoration and education. Land trusts are often instrumental in bringing "strange bedfellows" together to accomplish conservation objectives, and may be in a position to demonstrate innovative land use practices that commercial enterprises are reluctant to try. Consequently, land trusts can have positive impacts disproportionate to the number of acres they directly hold in fee title or in conservation easements.

Soil Properties Influenced and Altered by Agricultural Operations in California's Great Central Valley

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Introduction

The view from roads in California's Great Central Valley is one of a series of straight lines delineating fields of crops. The lines typically run north-south and east-west, as they conform, in general, to the Township and Range System of the U.S. Survey of Public Lands. A series of squares dominate a satellite view of the valley. The squares on the east side of the valley generally are much smaller than the squares on the west side. The pattern of the crops and the size of the farms dramatically illustrate the differences between the east and west sides of the valley. Each square represents a significant and permanent change in the natural landscape.

According to the American Farmland Trust, California's Great Central Valley is the most threatened resource area in United States. This assessment is based on the market value of Central Valley agricultural production, the development pressure, and the quality of the land in the valley (American Farmland Trust, 1997).

The impact of urbanization on the soils is significant and permanent. Many soil properties also are permanently altered by such farming practices as land leveling and irrigation. Some of these impacts are obvious, such as those resulting from the application of irrigation water. Other practices are more subtle and have an indirect impact. An example is pumping water from deep wells, which contributes to subsidence. Subsidence, in turn, affects the geomorphology of the region and influences flooding.

California's Great Central Valley stretches more than 450 miles from Redding in the north to Bakersfield in the south. It encompasses more than 19,140 square miles, 88% of which is covered by farms and ranches (American Farmland Trust, 1995). The valley produces more than 250 different commodities worth more than 15 billion dollars a year.

Agricultural operations have a significant impact on the properties, classification, and management of soils. The impact of agricultural operations occurs not only near the surface of the soil but also deep into the soil profile, where the wetting front of irrigation water moves.

Agricultural operations that affect soil properties include land leveling for irrigation purposes, deep tillage or ripping, and cultivation. Ground-water withdrawal and the application of water for surface irrigation have caused subsidence, which, in turn, has changed the geomorphology in many areas on the west side of the valley. The surface irrigation of soils across most of the valley has caused numerous climatic changes, and moisture received from precipitation makes up less than 20 percent of the total water on the soils. Some soils are less saline-sodic or saline now than they were prior to irrigation, but other soils are becoming saline-sodic. Saline-sodic and saline soils were partially reclaimed by the addition of soil amendments and leaching of the salts. Perched water tables have resulted from poor drainage and the application of surface irrigation water. Major water management structures, such as dams and canals, have slowed or stopped alluvial fan deposition in most areas.

Land Leveling for Irrigation

Extensive land leveling has taken place throughout the Central Valley. This practice has had a significant impact on the soil depth and the depth to diagnostic horizons. Land leveling has cut soil material from the higher sides of fields and filled the lower sides of fields with the cut soil material. On the high sides, this practice exposes soil horizons that are normally evident deeper in relatively unaltered soils, and on the low sides, it buries the surface layer under fill material.

Land leveling has a profound impact on soil classification. Identification of diagnostic horizons can be difficult when the surface has been altered by the removal or addition of soil. Subsoil horizons can be significantly altered and, in some cases, destroyed by this practice. It can be very difficult to document and identify increases in the clay content of a horizon that has been removed or in one that has been covered by unrelated soil material.

Land leveling commonly destroys or significantly alters soil structure. Identification of soil horizons in the absence of strongly expressed characteristics becomes difficult because of the degree of alteration.

Deep Tillage or Ripping

Many fields are ripped to a depth of 24 inches. This practice affects soil horizons to a depth of at least 30 inches. Some areas are ripped to a depth of more than 60 inches.

The purpose of ripping is to modify naturally occurring restrictive layers as well as the artificial layers created by past agricultural operations. Generally, naturally occurring restrictive layers, such as horizons with a significant increase in clay content, are deeper than artificial restrictive layers. In the Central Valley, ripping alters hardpans (duripans), dense soils with an increase in clay content in the subsoil, stratified soils, saline-sodic soils, clayey soils, and soils that have been affected by compaction, including natural compaction and the compaction that results from farming practices.

Deep ripping affects the surface layer, the subsoil, and the upper part of the substratum. It is difficult to document the resultant mixture of surface and subsoil horizons. Even where a subsoil horizon can be identified in a given area, it is difficult to determine whether the observed depth to the horizon is typical of the soil that occurred naturally in that area. The typical depth to subsoil horizons can be deceptive in areas affected by agriculture. An intact subsoil horizon may just be unusually deep subsoil that extended below the effect of the land-leveling equipment or the ripper shank pulled behind a tractor.

Ripping and modification of hardpan (duripan) horizons, particularily in granitoid parent materials on the east side of the Great Central Valley, has occurred through much of this century (Nikiforoff, 1941). Deep ripping of duripans has altered the sequence and continuity of soil horizons permanently. Use and management of a soil with a duripan that has been ripped is significantly different from use and management of a soil that has not been ripped. Ripping of the duripan has improved drainage and provided a deeper root zone for crops.

Deep ripping also has had a significant impact on soil structure. Prismatic and columnar structure and slickensides are often destroyed. Changes in the grade, size, and type of soil structure are common. Soil structure is one of the required characteristics of many subsoil horizons, and ripping often obliterates this structure, making classification of soils with weakly expressed subsoil horizons problematic (Soil Survey Staff, 1998).

Cultivation

Cultivation for such practices as seedbed preparation has impacts primarily on the upper foot of the soil. These impacts include changes in soil structure grade, size, and type; destruction of organic matter; mixing of surface horizons; possible accelerated erosion; and possible development of a compacted layer known as a plowpan. Development of a compacted layer directly below the surface of the soil may necessitate the use of deep ripping to provide a deeper root zone for crops and to improve drainage.

Organic Matter

Farming practices, such as disking, ripping, and leveling, have altered the distribution of organic matter in the Central Valley. Disking during the summer months exposes the organic matter in the soils to high temperatures, which can reduce the amount of organic matter.

Accelerated Erosion

Accelerated erosion caused by human activities is as old as human history. The "Dust Bowl" of the 1930s comes immediately to mind, but evidence indicating accelerated erosion can be subtle. It is much easier to prove that erosion has human causes if it can be observed to be taking place over a given time span.

In the Central Valley and surrounding areas, accelerated erosion has occurred primarily through petroleum extraction activities, such as road construction and the construction of pads for oil wells; through cultivation and the resulting lack of cover on sandy soils; and through livestock grazing on highly sodic soils. Of these three activities, the effects of petroleum-extraction activities are the most obvious because of the exposure of bedrock in the areas affected by road building and the construction of pads for oil wells.

In the Soil Survey of Fresno County, California, Western Part (Arroues, 2006), cultivation of map unit 448 (Excelsior loamy sand, sandy substratum, 0 to 1 percent slopes, eroded) appears to have caused significant loss of the surface horizon. The surface horizon of loamy sand begins to erode quickly after the soil is cultivated and left exposed to the wind. Most of the soils demonstrating significant accelerated wind erosion in this survey area have sandy loam or coarser textures.

Subsidence

Land subsidence has occurred along the west side of the San Joaquin Valley part of the Central Valley as a result of the withdrawal of ground water and applications of water.

Subsidence Resulting From Ground-Water Withdrawal

Subsidence in the San Joaquin Valley is one of the great changes that human activity has imposed on the environment. The maximum subsidence totaled 29 feet by 1972. Throughout most of the San Joaquin Valley part of the Central Valley, subsidence has occurred so slowly and over such a broad area that its effects have gone largely unnoticed by most residents. Extraction of ground water in the San Joaquin Valley for irrigation purposes increased from 3 million acre-feet in 1942 to at least 10 million acre-feet in 1964 (Poland and others, 1975).

The San Joaquin Valley has the largest vertical subsidence (29.7 feet), the largest areal extent (5,400 square miles) of subsidence, and the largest volume (16 million acre-feet) of subsidence in the world because of ground-water withdrawal (Bertoldi, 1991). The 16 million acre-feet of subsidence is substantially the same as the amount of water derived from deformation of the interbeds in the aquifer system. The water thus derived is called “water of compaction” (Bertoldi, 1991). According to Lofgren (1977), this “volume is a onetime quantity of water mined from the reservoir.”

Construction of the California Aqueduct and withdrawal of irrigation water that it supplied reduced the amount of overdraft of the ground-water supply. Rates of land subsidence have slowed appreciably since 1972. During periods of drought in 1977 and the early 1990s, however, subsidence continued as a response to increased pumping of ground water.

One of the largest impacts resulting from land subsidence is change in the elevation and gradient of stream channels, drains, and other water-transporting facilities. This change results in entrenchment in many stream groups that fan onto the soils in the San Joaquin Valley. “Results show that the majority of channel incision observed in the lower fan has occurred since 1933, and it appears to be a direct response to land subsidence resulting primarily from ground water extraction” (Leclerc and others, 1998).

Intermittent streams, such as the Arroyo Pasajero, in the west part of Fresno County, are deeply entrenched as much as 35 feet into the alluvial fans of Pleasant Valley, east of Coalinga. Historically, these streams, including the Arroyo Pasajero, were much less entrenched into the alluvial fans (Leclerc and others, 1998). In areas where stream entrenchment occurred as a response to the subsidence that has occurred in the past 60 years, soils that were subject to flooding 60 years ago are not flooded now, because the stream is 30 feet below the alluvial fan surface in many areas.

Subsidence Resulting From Applications of Water

This kind of subsidence is defined as shallow or near-surface subsidence caused by applications of water on loosely consolidated mudflows or water-laden sediments. Shallow subsidence results chiefly from the compaction of deposits by an overburden load as the soil structure and pores are weakened by water percolating through the deposits for the first time.

In the Soil Survey of Fresno County, California, Western Part (Arroues, 2006), 43,550 acres have undergone severe shallow subsidence. Four map units are characterized by severe shallow subsidence—map unit 490 (Cerini sandy loam, subsided, 0 to 5 percent slopes), map unit 491 (Cerini clay loam, subsided, 0 to 5 percent slopes), map unit 492 (Panoche loam, subsided, 0 to 5 percent slopes), and map unit 493 (Panoche clay loam, subsided, 0 to 5 percent slopes). Shallow subsidence has made irrigation of crops difficult and has destroyed or damaged ditches, canals, roads, pipelines, electric transmission towers, and buildings (Bull, 1964).

Shallow subsidence has caused simple slopes to become complex slopes that cannot be leveled. Slopes generally are 0 to 5 percent. The frequency of flooding is affected as water is trapped in depressions caused by shallow subsidence.

Induced Flooding

Attempts to capture water from intermittent streams in the early 1900s severely affected hydrology in this survey area, since new channels and earthen dams introduced water onto fan remnants that normally would be flooded only on rare occasions. "Much of the water from creeks is used for irrigation within Pleasant Valley." (Harradine and others, 1952) Cropland thus was close to the elevation of the flood plain, making it easier to irrigate crops with the water from intermittent streams.

The sandier material was deposited on terraces because of the higher velocity of water, which often ran uncontrolled and cut huge swaths across the fan remnant, creating, in effect, a hanging channel.

Influence of Major Water-Management Structures

Dams and canals effectively slowed or stopped alluvial fan deposition in many parts of the Central Valley. The geomorphic responses to major water management-structures, such as dams, canals, and levees, have been significant.

Flooding characteristics were forever changed by the introduction of these structures. The best illustration is Tulare Lake, in Kings County, "once the largest body of fresh water west of the Great Lakes. Formed by the entrapped drainage of four Sierra rivers, the Kings, Kaweah, White, and Tule, its highest level was recorded in 1862. That year it covered 486,400 acres to depths exceeding forty feet" (Haslam, 1994). Tulare Lake rarely floods now because of the diversion of much of the Kings River water to valley farms and north through the Fresno Slough to the San Joaquin River along the eastern boundary of the survey area. The Tulare Lake Bed, located primarily in Kings County, is now an area of productive farmland.

Sedimentation and alluvial fan-building processes also have been altered. Natural alluvial fan-building processes are generally considered to be incompatible with such human uses as agriculture and rural and urban centers. Attempts have been made to alleviate these incompatibilities by confining water behind levees and dams. These attempts are successful for a time, but flooding eventually occurs. The flooded areas are not always the same areas that were flooded historically.

Irrigation and Climate

About 3 feet of irrigation water per year is applied for crop production to many soils in the Central Valley. Prior to the introduction of irrigation, only 7 to 9 inches of annual precipitation, coupled with floodwater, was available for soil development.

Irrigation has many effects on soil properties. The downward movement of carbonates, gypsum, fertilizers, salt, and various amendments through the soil profile has created cambic horizons (Soil Survey Staff, 1998). Zones of removal or concentration of these soil constituents are evidence of the alteration of soil to depths exceeding 24 inches. Cambic horizons are evidence of the effects of irrigation water. Many soils may have had a cambic horizon before irrigation in this semiarid environment. Some of the cambic horizons were altered or destroyed and then resurrected as newly formed cambic horizons.

Salinity and Drainage

The addition of soil amendments and the effects of salt leaching partially reclaimed saline-sodic and saline soils. Perched water tables resulted from poor drainage and the introduction of irrigation water. Some soils are less saline-sodic or saline now than they were before irrigation, but other areas are becoming more saline-sodic.

The Soil Survey of Fresno County, Western Part has about 380,000 acres of saline-sodic soils. This acreage constitutes approximately 48 percent of the irrigated land within the boundaries of this survey area, up from approximately 33 percent of the irrigated land so identified in
1985. This was an increase of approximately 120,000 acres in 18 years.

Irrigation with saline well water has increased soil salinity levels in some areas. In Pleasant Valley, near Coalinga, saline soils occur in areas that were formerly nonsaline (Harradine and others, 1952).

Closure of the San Luis Drain in 1986 halted or restricted the use of drain tiles in areas of the western part of Fresno County with high perched water tables, causing an increase of salts in the soil directly above the capillary fringe. The San Luis Drain was closed when high levels of selenium were discovered at Kesterson Reservoir, where the San Luis Drain ended. The Kesterson ponds acted as evaporation ponds, where selenium and salts were concentrated. Significant damage to wildlife resulted from the high concentrations of selenium in the food chain (Presser and others, 1990).

On approximately 290,000 acres in the western part of Fresno County, the soils have a perched water table within 6 feet of the surface. Since 1980, many of the soils in the area have developed a perched water table within 6 feet of the surface. Many of these soils have been classified as Aridisols or Vertisols that were well drained or moderately well drained. These soils have developed few features associated with wetness, but their perched water table affects their use and management. The Soil Survey of Fresno County, Western Part identifies these soils by adding the word “wet” to the map unit name.

The water tables are perched on layers or strata with significant changes in soil texture, generally within 30 feet of the soil surface. Perched water tables were initially lowered by the following forms of artificial drainage:

1. Dams and reservoirs
2. Pumping from the water tables

3. Filling and leveling of sloughs in the area where lateral water flow has been interrupted
4. Tile drains in fields (including tile drains that intercept seepage from a canal, river, or slough)
5. Levees that provide protection from very long periods of flooding

Most of the soils with a perched water table within 6 feet of the surface in the western part of Fresno County are currently cultivated. Most have been drained by dams, reservoirs, levees, and the filling and leveling of sloughs. Some of the soils also are drained by pumping from the water table and by tile drains.

Soil Amendments and Fertilizers

Personal communication with farmers in the western part of Fresno County indicates that as much as 250 tons per acre of gypsum has been applied to saline-sodic soils in many areas since reclamation of these soils began about 75 years ago. This practice has had profound effects on the soils. These effects include the following:

1. Sodium is leached from the profile. A natric horizon can become an argillic horizon.
2. Soil structure is changed because of changes in the composition of specific cations attached to the clay particles in the soil.
3. Soil reaction (pH) is reduced not only by application of gypsum but also by amendments, such as sulfur and sulfuric acid.

Fertilizers, such as ammonium sulfate, ammonium nitrate, and ammonium phosphate, also may affect the reaction of many soils to which they have been applied.

Summary

Agricultural operations have had and continue to have a significant impact on the properties, classification, and management of the soils in this survey area. Soil surveys are more beneficial if soil modification is addressed. In the Central Valley, soils that previous generations recognized are seldom evident today. These soil modifications have been recognized in this paper.

Present-day soil characteristics are important to users. It is important to describe and classify soils as they currently exist rather than depicting them historically. Providing current information about the soils permits an accurate portrayal of the use and management practices appropriate for the soils. Paradoxically, there is value in preserving the concept and legacy of the original soil. This effort will assist us in explaining the characteristics of the modified soil. The "roots" of the soil that we observe today have an attachment to the natural, unmodified soil. This connection between the past and the present is an important consideration when decisions regarding use and management of the soils are made. Unfortunately, there are few places in the valley where one can observe a natural soil profile (Amundson, 1998). As a result, it is difficult to determine exactly what the unmodified soil looked like.

One of the best sources of information about modified soils is historic soil surveys. Even historic soil surveys, however, commonly used modified soils when typical profiles for soil series were selected (Harradine and others, 1956). Understanding the soil as it currently exists requires knowing how the soil was modified and what soil properties have been changed.

Temporal or permanent change can then be explained. With this understanding, some of the changes that may occur in the future can be projected and map units that are more adapted to those changes can be designed.

Literature Cited

American Farmland Trust. 1995. Alternatives for future urban growth in California'sCentral Valley: The bottom line for agriculture and taxpayers.

American Farmland Trust, Sorensen, A.A., R.P. Greene, and K. Russ. 1997. Farming on the edge.

Amundson, R. 1998. Are soils endangered? The vanishing undisturbed soils of the west.

Arroues, K.D., 2006. Soil survey of Fresno County, California, U.S. Department of Agriculture, Natural Resources Conservation Service.

Bertoldi, G.L. 1991. Subsidence and consolidation in alluvial aquifer systems. Proceedings of the 18th Biennial Conference on Ground Water, U.S. Geological Survey.

Bull, W.B. 1964. Alluvial fans and near-surface subsidence in western Fresno County, California.

Harradine, F.F., R.A. Gardner, L.G. Rooke, and E.A. Knecht. January 1956. Soil survey of the Mendota area, California. Soil Survey Series, 1940, No. 18. U.S.

Department of Agriculture, Agricultural Research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering.

Harradine, F.F., A. Smith, L.H. Smith, H.A. Hannesson, G.L. Huntington, C.R. Horton, E.P. Whiteside, E.W. Stevenson, and P.T. Veale. December 1952. Soil survey of the Coalinga area, California. Soil Survey Series, 1944, No. 1. U.S. Department of Agriculture, Agricultural research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering.

Haslam, G.W. 1994. The other California. The Great Central Valley in life and letters. The lake that would not die.

Leclerc, R.F., R.C. MacArthur, and V.J. Galay. 1998. Arroyo incision due to tectonism and land subsidence, Arroyo Pasajero, California. NW Hydraulic Consultant. Sacramento, CA and North Vancouver, BC, Canada. 7 pp.

Lofgren, B.E. 1977. Changes in aquifer system properties with ground water depletion. Proceedings of the 11th Biennial Conference on Ground Water, Sacramento, California, September 15-16, University of California Water ResourcesCenter, Davis, California.

Nikiforoff, C.C. 1941. Hardpan and microrelief in certain soil complexes of California. U.S. GPO. Washington D.C. 46 pp.

Poland, J.F., B.E. Lofgren, R.L. Ireland, and R.G. Pugh. 1975. Land subsidence in theSan Joaquin Valley, California, as of 1972. U.S Geological Survey Professional Pape 437-H.

Presser, T.S., W.C. Swain, R.R. Tidball, and R.C. Severson. 1990. Geologic sources mobilization, and transport of selenium from California Coast Ranges to the western San Joaquin Valley: A reconnaissance study. U.S. Geological Survey, WRIR 90-4070,Menlo Park, California.

Soil Survey Staff. 1998. Keys to soil taxonomy. 8th edition. U.S. Department ofAgriculture, Natural Resources Conservation Service.

A Systems Approach To Conservation Tillage And Nutrient Management In The Production Of Dairy Forages

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Summary

One dairy farmers approach to managing dairy forage production using conservation tillage systems. The presentation will compare the reduced tillage program with conventional till as well as describe a nutrient management program which includes triple cropping.

Development the Lettuce and Leafy Green Agreement

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Introduction

Based on the overall consumption of fresh produce, illness definitively associated with contamination that occurs prior to food preparation is a very low probability event.

However, outbreaks linked to fresh produce from various production areas have occurred and have impacted large numbers of individuals across many states and into Canada. These outbreaks have gained international attention and have led to a significant erosion of confidence in the safety of leafy greens.

Whether domestically produced or imported, key finding have increased the focus and concern for the microbial food safety of fresh leafy greens:

1) Reoccurring outbreaks
2) Positive detection and recovery of human pathogens from random survey sampling
3) Recent research documenting the difficulty of cleaning and disinfecting produce surfaces.
4) Recent research documenting the potential for internalization of pathogens during postharvest handling
5) Media and government activism calling for food safety regulations for leafy greens production

This talk will present the rationale behind industry efforts to proactively address several of these key findings and efforts to improve food safety practices for the production and harvest of leafy greens. The talk focuses on the steps taken to prevent contamination in the field as well as other parts of the supply chain and the use of state and federal marketing authority to create industry programs to improve food safety and restore public confidence in the leafy greens sector.

Presentation Topics

- Background
- The California Leafy Greens Marketing Agreement
- Good Agricultural Practices (GAPs)
- The Service Mark
- Compliance Audits
- Penalties and Decertification
- The Arizona Leafy Greens Marketing Agreement
- Federal Activity on Leafy Greens Food Safety
- Questions and Answers

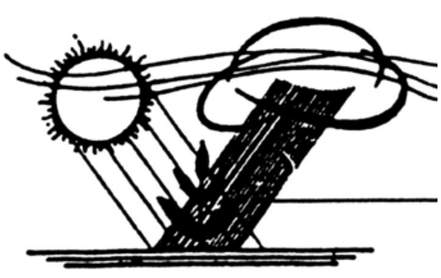
Session V

Plant & Soil Nutrition

Session Chairs:

Joe Fabry, Fabry Ag Consulting

Will Horwath, UC Davis-LAWR



N-P-K and Calcium Uses in Drip Irrigated Onions & Tomatoes

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Introduction

Water and fertilizer should be managed differently for drip-irrigated compared to furrow-irrigated crops. Drip irrigation allows growers to make more frequent irrigations, which can leach N fertilizer away from crop roots. However drip irrigation also allows growers to make frequent fertilizer applications of lesser amounts, which keeps the crop constantly supplied and minimizes the problem of leaching. Lesser total amounts of applied fertilizer combined with more refined water management can result in fertilizer savings and higher crop yields. This can be a benefit to growers and is more environmentally friendly.

Almost all fresh market onions grown in California now are drip irrigated. Estimates indicate almost 50% of the processing tomato acreage in California is grown using drip irrigation and furrow irrigation is on the decline. Sprinkler irrigation usually results in fruit disease problems and is not the preferred method of irrigation for either of these crops except in stand establishment.

Drip irrigation has the advantage that fertilizer and water can be applied efficiently and as frequently as the grower would like. This generally results in higher yields. One disadvantage with frequent irrigation is the development of a smaller root system, which may lead to less area explored by roots for nutrition.

Fertilizer rates and sources for fresh onion and processing tomatoes are quite different between furrow and drip irrigation regimes. Use of slow release fertilizers or combinations of slow and conventional fertilizers may have the potential to reduce leaching. Perhaps fertilizer additives are useful in enhancing nutrient uptake in crops with reduced root systems. There is limited information on how these types of fertilizers or their application methods perform under drip irrigation.

Fertigation experiments were needed to evaluate the most effective rates and sources of N-P-K and calcium. Nutrition and irrigation field studies were conducted in 2005-2007 on fresh onion and processing tomato crops in Fresno County at the UC West Side Research and Extension Center. All field trials were conducted using subsurface drip irrigation.

Table A: Fresh Market Onion Drip Irrigation and Fertilizer Field Studies
UC WSREC, Fresno County - 2006 and 2007

Variety	CHIEF
Plant	week of January 22
Harvest	week of August 25
Irrigation	Solid set sprinklers for emergence and to apply herbicide. Subsurface DRIP, started May 1 (onions were 4-6" tall), stopped July 25
Soil	Panoche Clay Loam
Nitrogen in Soil	Total N level before planting = 0.06%

Table B: Processing Tomato Drip Irrigation and Fertilizer Field Studies
UC WSREC, Fresno County - 2006 and 2007

Variety	H 9780 & H 9665
Plant Method	Direct Seeded
Plant	Early March
Harvest	Mid August
Irrigation	Solid set sprinklers for emergence and to set herbicide. Subsurface DRIP started after layby. 6-inches (sprinkler) + 18-inches drip = ~24" total
Soil	Panoche Clay Loam
Nitrogen in Soil	Total N level before planting = 0.06%

Table C: Products Tested in Fertilizer Field Studies at UC WSREC, 2006- 2007

Products *(all are liquid)*	**Company**	**Contents**
NITROGEN sources		
UN 32		urea & ammonium nitrate (UAN)
CAN 17		calcium ammonium nitrate
CN 9		calcium nitrate
other CALCIUM sources		
CalMax Premium (9-0-0)	Western Farm Service	10% Ca, 2% B, 0.1% Fe & Mn, 0.6% Mg, 0.3% Zn
CaTs	Tessenderlo Kerley Co.	Calcium thiosulfate (6% Ca, 10% S)
N-INHIBITORS (added to conventional N fertilizer to delay N release)		
Agrotain N-Stabilizer	Agrotain Int'l	Controls volatilization of UAN
GP 39	Georgia Pacific	80% CAN 17 + 20% NFusion
GP 40	Georgia Pacific	60% CAN 17 + 40% NFusion
GP 33	Georgia Pacific	80% UN 32 + 20% NFusion
GP 07	Georgia Pacific	60% UN 32 + 40% NFusion
ENHANCERS		
Acadian (0.3- 0.0- 5.0)	Acadian Agritech	100% Seaweed concentrate
Horizon	Horizon Ag Products	liquid soluble humus (humic acids +)

RESULTS

Table 1: Onion yield- Nitrogen rates and sources
Field studies conducted in 2006 and 2007 investigated N sources and rates for fresh market onions. The nitrogen treatments were applied in 7 weekly applications. Nitrogen sources such as UN 32, CAN 17, and CN 9 resulted in no significant differences in onion crop yield (tons per acre) when applied through drip irrigation. Therefore the N source could be based on lowest cost per pound of N. Highest significant yields of onions were obtained with 150-200 pounds of N.

Table 2: Onion yield - Slow release compared to conventional nitrogen
In a 2007 onion fertilizer study N-inhibitor products (listed as slow release) were compared to conventional UN 32. These N-fertigation treatments were initiated in mid May, when the onions started to form bulbs. Results show that at lower rates of N, the GP products (applied in 3 applications) yielded more than the conventional UN 32 (applied in 7 applications). At higher N rates conventional UN 32 (7 applications) yielded better than the GP products (3 applications), most of the time.

The UN 32 and Agrotain treatments were divided into 7 weekly applications. Performance by Agrotain was comparable to UN32 at lower rates, but at higher rates Agrotain was poorer. For the GP products the nitrogen was divided into 3 weekly applications and results were not consistent between the two blends.

Table 3: Onion yield - The effect of additives and enhancers
The effect of additives (such as calcium, humic acid plus, and seaweed concentrate) are believed to have a beneficial effect on fruit quality and yield. Fruit quality issues include fruit firmness, improved processing, and shelf life. Acadian foliar was the highest yielding treatment but not significantly different from the check UN 32. None of the other additives had a significant effect on yield. The foliar application of Acadian was a better method than the drip application.

Table 4: Onion firmness - The effect of additives and enhancers
In two years of studies no significant difference in bulb firmness was observed with the use of these additives. However, these studies will be repeated because there is a chance that the sample size was too small to observe real differences. There is a trend for some calcium products to give firmer bulbs than UN 32 or CAN 17.

Table 5: Onion - Phosphorus affect on yield and bulb firmness
In order to determine how much phosphorus was beneficial in drip irrigated onions, a separate study was conducted in 2006 and 2007 to look at phosphate rates. All phosphate was applied preplant and mulched on the top of the bed. None was applied through the drip system. Rates ranged from 0- 416 lbs/acre.

Results show there was no significant yield increase from the check with any of these rates. A yield response is generally expected with phosphate fertilizer applications in a winter planting of onions in cold soil, but under these conditions with 8 ppm phosphorus in the soil, there was no significant response. Still adding at least 50 lb P_2O_5 per acre as a preplant application is recommended.

Another reason for this study was to see if phosphate fertilizer applications improved bulb firmness, as was believed by industry. Two years of study revealed no bulb firmness differences between phosphate rates (data not shown).

Table 6: Onion - Irrigation requirements under drip
Traditionally it was thought that 100 - 120% ETc would result in maximum onion yields. Drip irrigation studies conducted in 2006 and 2007 revealed that the highest yields were obtained at 140 - 160% ETc, which is considerably more water than previously thought. Another component of this trial investigated the influence of higher irrigation rates on fruit quality. In two years of studies there was no detrimental effect on Brix % or bulb firmness, which was contrary to what was expected.

Table 7: Tomato - Nitrogen sources and rates
Two combinations of N-inhibitor products (slow release fertilizer) was compared to UN 32 in drip irrigated processing tomato in 2007. There was a slight trend for increased yield of the slow release fertilizer compared to the conventional (UN 32), and the higher rates tended to be better than the lower rates. The most economical treatment for maximum tomato yield was 200 pounds of N per acre with 150 lbs applied through drip.

Table 8: Tomato - Phosphorus response and method of application
Two field studies investigated phosphate (P_2O_5) rates and method of application in tomatoes. In 2006 three rates were compared to two methods of application: all P_2O_5 applied through the drip system or all P_2O_5 applied as sidedress applications. Applying 100 pounds of P_2O_5 through the drip system yielded better than 150 pounds sidedressed. Highest tomato yields were obtained with 150 pounds P_2O_5 through drip.

The field study in 2007 followed the same trend, but this year the highest yield was obtained when P_2O_5 was applied through the drip and as a sidedress application (a combination of application methods).

Table 9: Tomato - Potassium effect on yield and soluble solids
Industry suggests that late application of potassium chloride (KCl) through drip systems may increase yield and soluble solids. Trials tested different rates of potassium and their effect on tomato yield and solids. Rates from 0 to 120 pounds of potassium were used and no significant differences were found in increased yields or increased solids.

Table 10: Tomato - Irrigation: A balance between yield and solids
In commercial furrow irrigated tomato production the common practice is to cut water off from the crop 20-40 days before harvest in order to achieve acceptable yields and high solids. This practice has been a proven disaster in drip irrigated tomato production. A field study compared 20 commercial varieties for three years with different water stress levels from 100% ETc down to 65% ETc during the last 60 days before harvest. Water was stopped in all treatments about 10 days before harvest.

The best yield results were obtained with irrigation stress levels of 95% of ETc, but the significantly lower solids at 110% ETc resulted in the least tons of solids per acre. The best treatment from a grower perspective is 80-95% ETc giving the highest yield, intermediate solids, and high tonnage of solids per acre. The driest treatment 65% of ETc gave the lowest yield and the highest solids and produced the same tons of solids as 80-95% ETc.

Observations about Onions under Drip Irrigation

1. Nitrogen rates of 150-200 lbs/acre provided maximum yields. With different N levels in different fields, growers can fine tune their rates by using tissue analysis.
2. Source of nitrogen doesn't seem to make a difference in yield or bulb firmness of onions.
3. Using a starter fertilizer containing P_2O_5 on soils that are not deficient in P is still recommended.
4. Additives may have some benefit in fruit quality (need further study), but they have not been consistent in yield increases.
5. It appears that 140-160% ETc provides highest yields in the lower San Joaquin Valley. This amount of applied water did not have any detrimental effect on bulb solids or firmness.

Observations about Tomatoes under Drip Irrigation

1. Nitrogen rates of 150-200 lbs/acre are recommended for drip irrigated processing tomatoes. This is 50-100 pounds more than furrow irrigated tomatoes.
2. Phosphorus - If soils are low in phosphate (<8 ppm) prior to planting, then applying fertilizer with rates up to 200 lbs P_2O_5 per acre can substantially increase yield (15 tons in these trials).
3. Applying phosphate through drip may be more advantageous than applying phosphate as a sidedress, but in low phosphorus soils it appears that split applications of phosphorus in drip and as a sidedress would give maximum yields. Soils with phosphate levels above 8 ppm would likely only need phosphorus applied through the drip.
4. Potassium chloride (KCl) did not increase yields or solids with late season applications of 120 lbs K/acre.
5. Drip irrigation management is critical to obtain high solids and high yields and is more complicated than furrow irrigation, but has the potential to give higher yields and solids if managed properly.

SUMMARY - In these drip irrigation studies …

- Onions and tomatoes use the same amount of N (about 200 lbs/acre) to yield 50-70 tons/acre.
- Slow release nitrogen fertilizers did not yield much differently than conventional fertilizers in onions and tomatoes, but formulations and timings are still being evaluated.
- Onions require about 33% MORE water than tomatoes to achieve maximum yield.

References

Hartz, T.K. 2007. Fertility Management of Processing Tomato. Proc. Plant & Soil Conference, 2007. p. 71-75.

Hanson, B.R. and D.M. May (2006) "New crop coefficients developed for high-yield processing tomatoes", California Agriculture: Vol. 60: No.2, p.95.

Hartz, T.K., P.R. Johnstone, D.M. Francis, and E.M. Miyao. 2005. Processing Tomato Yield and Fruit Quality Improved with Potassium Fertigation. HortScience 40(6):1862-1866.

Hartz, T.K., G. Miyao, R.J. Mullen, M.D. Cahn, J. Valencia and K.L Brittan. 1999. Potassium requirements for maximum yield and fruit quality of processing tomato. J. Amer. Soc. Hort. Sci. 124:199-204.

Voss, R.E. and K.S. Mayberry. 1999. Fresh-Market Bulb Onion Production in CA. UC DANR pub #7242. 4 pages.

Table 1: Drip Irrigation Study
Effect of N Rate and Source on Fresh Market Onion Yield

N- source*	lbs/A	Yield Tons/A 2006		Yield Tons/A 2007		Avg
UN 32	100	**52**	g			
	150	**62**	abcde	**58**	j	
	200	**62**	abcde	**70**	ab	**66**
	250	**65**	ab	**71**	ab	**68**
	300	**58**	cdef	**70**	ab	**64**
					avg	**66**
CAN-17	150	**63**	abcd			
	200	**59**	abcdef	**70**	ab	**65**
	250	**60**	abcdef	**68**	bcd	**64**
	300	**60**	abcdef	**70**	abc	**65**
					avg	**65**
CN-9	150			**63**	fghi	
	200			**68**	bcd	
	250			**70**	ab	

* 7 weekly applications through drip after bulbing started (May 11 - June 22)

Table 2: Drip Irrigation Study
Comparison of Slow Release Fertilizers to UN 32

Onion Yield - Tons/Acre

		Conventional		Slow Release					
Total N	**N in drip**	**UN 32***		**GP 39****		**GP 40****		**Agrotain***	
150	**100**	**58**	j	**66**	c-f	**62**	g-i	**61**	h-j
200	**150**	**70**	ab	**67**	b-d	**63**	e-i	**62**	g-i
250	**200**	**71**	ab	**64**	d-h	**67**	b-f		
	avg	**66.3**		**65.7**		**64.2**		**61.5**	

* UN 32 and Agrotain - 7 weekly applications (May 11 - June 22)
** GP products – 3 weekly applications (May 11 - May 25)
GP 39 = 80% CAN 17 + 20% NFusion
GP 40 = 60% CAN 17 + 40% NFusion

Table 3: Effect of Additives on Onion Yield

	Additive*	Total N Lbs/A**	Onion Yield Tons/A	
Acadian – foliar* **	seaweed	200	**72.5**	a
CaTs (20 gal)	Calcium + sulfur	200	**70.4**	ab
CalMax Premium + AMS	calcium	200	**70.1**	ab
Check plot UN 32		200	**70.3**	ab
CaTs (40 gal)	Calcium + sulfur	200	**69.2**	ab
CalMax Premium	calcium	200	**67.5**	b
Horizon	humic acid plus	200	**66.9**	b
Acadian - drip	seaweed	200	**66.8**	b

*7 weekly applications after bulbing started (May 11 - June 22)
**All treatments received 200 lbs N/A as UN 32 (50 lbs preplant + 150 lbs through drip)
*** Foliar applications applied on May 18 and June 1

Table 4: Effect of Additives on Onion Bulb Firmness

	Bulb Firmness (psi)		
	2006	**2007**	**Avg**
CalMax Premium	21.9	23.7	22.8
CN 9	--	23.2	--
Horizon	22.1	22.7	22.4
CaTs	22.0	23.1	22.5
UN 32	20.5	22.6	21.5
CAN 17	21.5	21.9	21.7
	NS	**NS**	**NS**

Table 5: Effect of Phosphate* on Onion Yield

	Onion Yield Tons/Acre		
P_2O_5	**2006**	**2007**	**Avg**
0	40.4	55.2	47.8
52	43.0	57.5	50.3
104	46.1	55.0	50.5
156	---	53.7	--
208	45.7	51.6	48.7
312	45.3	---	
416	44.4	---	
	NS	**NS**	**NS**

* All phosphate applied preplant; Soil P (Olsen) 8 ppm each year (field location was side by side)
Onions planted late January, harvested late August

Table 6: Effect of Applied Water on Yield and Quality of Drip Irrigated – Fresh Market Onions

% ETc	Water applied thru drip (inches)	Yield T/A	Water applied thru drip (inches)	Yield T/A	Brix %		Bulb Firmness psi	
	2006		2007		2006	2007	2006	2007
80	14	34.4 c			7.7	---	23.3	---
100	17	48.4 b	17	58.6 b	7.4	8.1	22.7	23.0
120	21	52.0 b	19	64.1 ab	7.5	8.3	22.6	24.6
140	25	58.6 a	21	65.0 ab	7.9	8.4	23.2	25.5
160	26	61.6 a	23	70.4 a	7.2	8.5	23.3	26.6
		LSD at .01%			**NS**	**NS**	**NS**	**NS**
		CV = 7%						

Pre-irrigation + sprinkler irrigation was 12" water applied prior to drip.

Drip irrigation was started when the plants were 3-4 inches tall.

Applied water of 100% treatment was determined from standard crop coefficients of onion and reference crop ET.

Table 7: Drip Irrigation Study
Comparison of Nitrogen Slow Release Fertilizers to UN 32
Tomato Yield - Tons/Acre - 2007

		Conventional	Slow Release		
Total N	**N in drip**	**UN 32***	**GP 07****	**GP 33****	**Avg**
Lbs/Acre		**Tons/Acre**			
150	**100**	57 c	59 abc	57 c	**57.7**
200	**150**	59 bc	62 ab	63 ab	**61.3**
250	**200**	61 abc	64 a	62 ab	**62.3**
	avg	**59.0**	**61.6**	**60.6**	**60.4**
LSD@0.05%			CV = 5%		

* UN 32 - Seven weekly applications (May 24 - June 28)

** GP products – Three weekly applications (May 24 - June 7)

GP 33 = 80% UN32 + 20% NFusion

GP 07 = 60% UN32 + 40% NFusion

Preseason soil sample top 18-inches: NO_3^--N = 20 ppm and NH_4^+-N = 8 ppm)
~160 lbs of potential available Nitrogen

Table 8: Effect of Phosphorus Rate and Placement Method
Processing Tomato Yield - Tons/Acre

	P_2O_5 (lbs/A)						
	0	**50**	**75**	**75 + Foliar****	**100**	**150**	**175**
2006							
drip		**42.5** c			**46.8** b	**49.1** a	
sidedress		**42.8** c			**43.5** c	**46.1** b	
2007							
check	**49.8** d						
drip			**63.2** b	**62.9** b		**64.4** b	
sidedress					**57.4** c		
drip + sidedress							**67.7** a
	LSD @ 0.05			CV=3.5%			

Preseason soil P level = 2 ppm (Olsen) in top 18".
Drip applied P = PhosAcid and Sidedress P = 11-52-0

* All plots received 25 lbs P_2O_5 preplant.
** 2 foliar apps (1 gal) Essential (3-17-17).

Table 9: Effect of Potassium Rate applied through Drip Irrigation on Yield and Solids of Processing Tomato*

Potassium	**Yield Tons/A**		**% Solids**	
Lbs/A	**2006**	**2007**	**2006**	**2007**
0	47.3	64.4	5.8	4.6
40		64.0		4.5
60	49.0	61.9	5.7	4.8
80		61.9		4.8
120	49.0	62.7	5.8	4.6
	NS	**NS**	**NS**	**NS**

2006 & 2007: Potassium applied as KCl in 2 applications through drip system ~45 and 30 days before harvest

Table 10: Effect of Applied Water on Yield and Solids of Commercial Processing Tomato Varieties Grown under Drip Irrigation

		Average of 20 varieties 2004, 2005 & 2006		
ETc* %	**Water applied thru drip (inches)**	**Yield Tons/A**	**Solids %**	**Solids Tons/A**
110	**18**	**49.1 a**	**4.9 b**	**2.4 a**
95	**16**	**49.9 a**	**5.2 a**	**2.5 a**
80	**14**	**48.0 a**	**5.3 a**	**2.5 a**
65	**11**	**44.8 b**	**5.4 a**	**2.5 a**

*10-12 inches water applied by sprinkler prior to drip irrigation. ETc differences initiated 60 days before harvest.

Boron Nutrition of Grapevines

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Introduction:

Boron deficiencies can occur on the east side of the southern San Joaquin Valley on alluvial and colluvial soils with igneous parent material (mostly granite) from the Sierra Nevada Mountains. In igneous rocks boron content is low and bound in borosilicate minerals, which are resistant to weathering and release B slowly. Boron is never found in its pure form in nature but is combined with oxygen, sodium, silicon, calcium, and water to form minerals. In soil, available B is held by the organic and clay fraction through complexing and anion adsorption, thus B levels are lowest in sandy, low organic matter soils.

Boron deficiency is not wide spread on the east side of the San Joaquin Valley. When symptoms of deficiency occur, it's usually found on sandy soils, in low spots, or near irrigation valves where excessive leaching with irrigation water occurs. Vineyards are subject to deficiency when primarily irrigated with canal water originating in the Sierra Nevada or well water low in B content or during high rainfall years. Deficiency levels that do not result in symptoms expressed in the foliage affect fruit set and yield. Therefore, fertilizing the vineyard is warranted when tissue analysis suggests than B levels are approaching deficiency or when symptoms of deficiency are noted, even in a few vines. The cost of treatment is relatively low and B deficiency can drastically affect yield.

Boron toxicity on the east side is rare and almost always associated with over fertilization with B. Boron toxicity, however, can be a serious problem on the west side of the San Joaquin Valley and in coastal districts. Soils in these districts have parent material associated with the marine sedimentary rocks of the coast range that have a high B content. Boron minerals such as borax, kernite, ulexite, colemanite can be plentiful in dry lake and seas bottoms and associated sedimentary and metamorphic rocks. Boron in the form of borax and kernite has been mined in Kern, San Bernardino, and Lake Counties from shale and dry lakebeds.

Boron deficiency occurs when uptake from soil is inadequate to support new growth. The most serious and common effects are on berry set and growth. In severely affected vines, a poor fruit set at bloom can result in almost no crop. More moderately affected vines will have many clusters that set numerous "shot berries" that are distinctive in size and shape. Shot berries are uniform in size and round to somewhat flattened on the ends, "pumpkin" shaped, and they ripen uniformly. Mildly deficient vines may only show fruit symptoms, demonstrating that fruit set is the vine function that is most sensitive to low B. Foliar symptoms will appear as the severity of deficiency increases. Affected leaves show irregular, yellowish mottling between the veins. Some shoot tips stop growing and die. After a few weeks, vines resume normal growth, which hides the symptomatic leaves.

Toxicity on the east side of the San Joaquin Valley is associated with excessive B fertilization. Leaf symptoms associated with toxicity are quite distinctive. In the spring, young leaves will show downward cupping and puckering becoming contracted and wrinkled. These symptoms are most commonly observed when foliar B is applied in amounts greater than ½ pound B per acre in a single application (2 ½ pounds 20.5% B soluble product per acre). Boron uptake by the sprayed tissues is rapid. However, vines quickly outgrow symptoms resulting from foliar application of B, and within a few weeks affected leaves are obscured by new, healthy, vine growth. Fruit set and berry development do not appear to be negatively affected. However, foliar symptoms can be much more protracted when B is applied in excess to the soil and production can be negatively affected.

Midsummer or late summer symptoms of boron toxicity are a brown speckling pattern adjacent to the leaf margin of mature leaves. Mature leaves show little cupping but the necrotic specks near the leaf margin can become so numerous that they seem to be continuous from the edge inward. Midsummer and late summer symptoms indicate excessive soil B. Correction requires additional irrigation to leach the excess B from the root zone.

Research on drip applied boron:

Studies were conducted during the 1998 and 1999 season in a mature Thompson Seedless vineyard on Cajon sandy loam in Tulare County. The soluble B product (20.5% B) was applied to an excavation beneath drippers simulating fertigation. Boron was applied at different rates three weeks prior to bloom on May 18, 1998. This was repeated the following year, again about three weeks prior to bloom on May 3, 1999. The experiment was designed as a randomized complete block with 5 treatments, five blocks, and five vine plots.

Boron drip irrigation treatments were as follows: Control, untreated; Boron applied at 1/3 pound per acre, 1998 & 1999; Boron applied at 2/3 pound per acre, 1998 & 1999;
Boron applied at 1.0 pound per acre, 1998 & 1999; Boron applied at 1/16 pound per acre, 1998, 2 pounds per acre, 1999.

Tissue samples were collected at bloom and veraison in 1998 and 1999 to evaluate rate of B uptake and the accumulation of B in tissue with consecutive years of fertilization. Samples were again collected two years later in 2001 to evaluate carryover. Results of analysis are shown in tables 1 and 2 and in figure 1.

This study has demonstrated that 1-pound actual B per acre (5 lbs. 20.5% B soluble product) can be safely applied to mature vines through drip irrigation, even in a single application. An annual application of 1-pound B per acre applied for three or four consecutive years will probably result in excessive levels in tissue. For maintenance, apply 1-pound through the drip system every three or four years or ¼ to 1/3 pound every year. For maintenance, B can be applied any time of the year. However, to correct a diagnosed deficiency, apply before dormancy if possible to increase B levels in dormant bud tissue. Tissue sampling should be used to fine tune fertilizer amounts and avoid toxicity. Rates should be reduced when petiole levels reach 50 ppm B or blade levels reach 70 ppm B.

Vine uptake of drip-applied B is fairly rapid after application during the growing season: leaf tissues were significantly increased in three weeks with 2/3 and 1 pound B per acre rates applied pre-bloom in our studies. However, it may be advisable to apply some or all of the B in the fall in order to ensure that primordial shoot and inflorescence tissue in the buds is not affected by deficiency.

Apply no more than 1-pound B per acre per year for safety, and never apply the full rate to young, immature vines. One-year-old vines should only receive 1/3 pound of B per acre; two- and three-year-old vines should receive ½ and 2/3-pound B per acre per year, respectively. These more conservative rates are because of the known efficiency of fertilizer delivery with drip irrigation and grower experience of B toxicity in new plantings.

Research on foliar applied boron:

Studies were conducted in 1998 and 1999 in an own-rooted, furrow irrigated, Thompson Seedless vineyard on Delhi loamy sand. The Kingsburg area vineyard was selected due to the observance of severe boron deficiency symptoms in 1997. Boron was applied to the foliage at different stages of vine development. Fall foliar sprays contribute to soil B levels once leaves fall and mineralization occurs. To differentiate foliar and soil contributions to vine uptake from the fall foliar treatment, a dormant soil application was included in the experiment. Boron treatments were all applied at 1 lb. B per acre as 20.5% B soluble product. Trial design was a randomized complete block, with five blocks and five treatments and using 5-vine plots. Boron foliar and soil treatments were as follows: Control, untreated; Fall foliar, Oct. 19, 1998; Soil application as a berm spray, Feb. 8, 1999; Prebloom foliar, May 4, 1999; Bloom foliar (50% caps off), May 20, 1999.

Fruit response to treatment was determined by visually grading individual clusters for the presence of boron deficiency symptoms on August 15, 1999. This included as assessment of reduced fruit set and the presence of the characteristic, pumpkin-shaped shot berries. Fifty clusters per plot were individually scored as percent of the cluster showing the combined symptoms of fruit set and shot berries. The data in Figure 4 are reported as "incidence" (average number of clusters (%) per plot showing some symptoms) and "severity" (average number of berries per cluster (%) showing symptoms in a plot).

This study showed that correction of a deficiency might not be immediate due to restricted mobility within the plant and continued development of deficient tissues. Pre-bloom and bloom sprays were only partially effective in preventing deficiency at bloom and fruit set. Fall foliar sprays were more effective in eliminating cluster and berry symptoms the following year. This corresponded with an increase in the B content of dormant buds and suggests that low boron levels in primordial tissue in early spring can negatively affect flower cluster development.

Leaves are more tolerant of B applied at fall, and B can be applied to foliage at 1-pound B per acre in a single application with no consequence. Fall applications should be made soon after harvest for leaf and vine uptake. Ultimately, all of the residual spray B is washed into the soil with winter rainfall, further supplying soil B for root uptake. After one or several years of treatment, there should be enough residual B in the soil to provide for a more constant uptake and long-term correction. Then, one can conveniently spray B at any time of the year to achieve maintenance.

Commercial B spray products include 10% B liquid, 17.5% B dry flowable and 20.5% B powder. All of the materials should be equally effective at the same rates of elemental B per acre. They also increase spray tank water pH and should not be combined with alkaline pH-sensitive products without pH adjustment with a recommended acidifier. Follow label instructions.

Summary:

Research was conducted with boron fertilization by drip irrigation and with foliar application from 1988 to 2001. New information developed by these studies follows: 1. Vine uptake of drip-applied B is rapid. Boron concentration of leaf tissue is elevated within three weeks of application; 2. 1-pound actual B per acre (5 lbs. 20.5% B soluble product) can be safely applied to mature vines through drip irrigation, even in a single application; 3. An annual drip application of 1-pound B per acre applied for three or four consecutive years can result in excessive levels in tissue; 4. For maintenance, apply 1-pound through the drip system every three or four years or ¼ to 1/3 pound every year; 5. In severely B deficient vineyards, pre-bloom and bloom sprays are only partially effective in preventing fruit symptom. Fall foliar sprays increase B content of dormant bud tissue and are more effective in eliminating cluster and berry symptoms the following year; 6. Leaves are more tolerant of B applied at fall, and B can be applied to foliage at 1-pound B per acre in a single application with no consequence.

Literature

Peacock, W.L. 2005. Fertigating drip-irrigated vineyards with macro- and micronutrients. In: Proceedings of the Soil Environment and Vine Mineral Nutrition Symposium. L.P. Christensen amd D.R. Smart, Eds. Am. Soc. Enol. Pp129-133.

Peacock, W.L. and L.P. Christensen. 2005. Drip irrigation can effectively apply boron to San Joaquin Valley vineyards. Calif. Acric. 59:188-191.

Christensen, L.P., R.H. Beede, and W.L. Peacock. 2006. Fall foliar sprays prevent boron-deficiency symptoms in grapes. Calif. Agric. 60:100-103.

Evaluation of the Amino Sugar Soil Test for Available N

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Introduction

One of the main technical reasons for the inability to determine application rates and timing of N fertilizers is that no good soil test method exists to predict soil N availability throughout the growing season. The barrier to developing a method to predict N availability is in the uncertainty in the amount of available N made available during a growing season from mineralization of recent crop residues, soil organic matter, and organic amendments. Across soil types and cropping practices, the quantity of N mineralized from soil annually ranges from very low (perhaps <20% of plant N requirement) to well above the plant N requirement. Until this uncertainty is addressed, the possibility of over applying fertilizer N remains and the environmental consequences of excess fertilization will remain an issue. Numerous soil analytical methods for mineralizable N have been published, and many have been shown to be effective under experimental and certain field conditions. Generally, these methods either require too much time to conduct (half year incubation in the laboratory) or are otherwise not suited for commercial laboratory usage; or they are effective only within a narrow set of soil and cropping conditions.

In recent years, soil nitrate testing procedures Ø for example the PSNT (pre-sidedress nitrate testing) and PPNT (preplant nitrate testing), have been advocated and to some extent adopted in the Midwest and Northeast US (Bundy and Andraski. 1993). Magdoff et al. (1994), improved the PSNT test by sampling available soil N within days of sidedressing fertilizer. In some instances, soil nitrate testing may be the best option for California farmers to reduce over-fertilization. However in many situations common in California, soil nitrate testing is ineffective, in particular, where root systems are shallow due to claypan or hardpan conditions and where the leaching fraction is unavoidably high (coarse-textured soils irrigated by furrow or border check). Under these conditions, soil nitrate content does not reflect the soil N mineralization potential. For example, Krusekopf et al. (2002) often found little correlation of PPNT to tomato yields. The limitation of testing for soil NO_3^- is related to the dynamic nature of the soil N cycle. The temporal nature of the available soil N pool negates the predictive capacity of the tests based solely on the amount soil NO_3^-. Therefore, in practice the PPNT and PSNT have only been marginally acceptable in assessing fertilizer N application rates. Even though these results seem not to be promising, soil testing for available N is still considered the best option to determine sites where N fertilization will produce a yield response.

Recent evidence points to amino sugars as being useful to determine soils that are responsive to N fertilization (Khan et al. 2001). Amino sugars account for up to 25 to 45% of the total soil N. Soil amino sugars are primarily derived from microbial and faunal sources. The size of the amino sugars pool will depend on the activity of the soil biomass. The production of soil biomass and its subsequent turnover release amino sugars to soil and this has been directly related to available soil N. The higher the available soil N pool, the more likely the amino sugar pool will also be high. The advantage of examining the amino sugar pool in soil is that it represents an index describing a fraction of soil N that contributes significantly to soil N availability. In addition, the timing of sampling is not as critical as for the PPNT or PSNT methods since the amino sugar fraction represents the activity of the soil biomass, which is more stable seasonally than the dynamic nature of soil nitrate.

Though the amino sugar technique has shown great promise in higher organic matter soils of the Midwest, its application in California needs assessing before it can be adopted. Testing is needed on low-organic matter, irrigated soils found in California. The challenge in testing and implementing the amino sugar method will be to determine soil characteristics, such as non-nitrogen nutrient levels and soil organic matter characteristics, which may affect the interpretation of the assay. The intent of this talk is to present results for the soil amino sugar test as a predictor of available soil N in California cropping systems.

Objectives

Assess the soil amino sugar method to predict N responsiveness in California.

Modify the method for adoption by soil test labs.

Collaborate with commercial soil test labs for method adoption and quality control.

Material and Methods

Soil samples

The methods comparison and development were carried out with soil samples with a wide range of texture and organic matter contents. The samples were taken form the top 20 cm of fields under row crops (a detailed description will be provided in the talk). The samples were air-dried and ground to pass a 2 mm sieve.

Soil amino sugar assay (Illinois Soil Test)

Amino sugars were analyzed using the diffusion method proposed by Khan et al. (2000, 2001). The method involves two analyses carried out with separate soil samples: Dried and crushed (2 mm) soil samples are treated in closed Mason jars either with a 2M KCl solution and MgO to convert ammonium-N to ammonia or with a 2M NaOH solution to convert ammonium-N and amino sugar-N to ammonia. A soil:solution ratio of 1:10 was chosen and 0.12 g MgO per g soil was added to the KCl solution. Five mL of boric acid (40 g H_3BO_3/L) contained in a Petri dish was suspended from the Mason jar lid . After the reagent additions, the jars were closed and placed on a hot plate (West Bend, model 76212) that was maintained at 48 to 50¡ C. The temperature of the plate was adjusted to heat 100 mL DI water in an open Mason jar, placed in the center or the griddle surface, to 48 to 50¡ C. The diffusion period was 5.5 hours to determine ammonium and 5 hours to determine amino sugar and ammonium. The liberated ammonia was collected in H_3BO_3 solution. After the diffusion period, the jars were allowed to cool before being opened. The boric acid solution was diluted with 10 to 15 mL of DI water and the Petri dishes containing the solution were weighed to take into account changes in weight during the diffusion period. The concentration of ammonium-N was determined colorimetrically . The amino sugar content is the difference between the two results.

Modified no-trap method amino sugar soil test

This method does not require an acid trap and can therefore be carried out in a small vial. The difference from the diffusion method is that at the end of the extraction period the pH of the whole solution is lowered to pH 7. The solution itself serves as an acid trap and can be analyzed for ammonium-N directly. Two grams of soil were weighed into 40 mL glass vials (Fisherbrand, economical glass; 40 mL). Twenty mL of 2M NaOH was added and the vials were closed immediately using open-top caps with septa liners. About 3 mL of air was extracted with a syringe to lower the maximum pressure during the analysis. The vials were then placed into a preheated water bath maintained at 50¡ C. After five hours, the vials were removed from the water bath, and 3 mL of 9M H_2SO_4 was injected with a syringe to lower solution pH. The vials were shaken on a reciprocal shaker for 15 minutes to increase the rate of the conversion of ammonia to ammonium. The solution was then filtered through a previously leached filter paper. Finally, the ammonium-N in the filtrate was determined colorimetrically using a spectrophotometer.

Results and Discussion

Method comparisons

We successfully modified and streamlined the soil amino sugar test for commercial laboratories eliminating the need for bulky analytical glassware and minimizing hazardous waste production outlined in the original method. The two methods, diffusion and the modified no trap method are very well correlated. The direct diffusion method recovers amino sugar-N almost completely. Only a minor part of the N released originates from other N sources such as amino acids and amines. With the no-trap method, more N is recovered because the ammonium-N, which remains in solution, is also measured. The successful miniaturization of the direct diffusion method makes it appealing to be adopted by soil test labs.

The no-trap method has several advantages over the diffusion method, which make it attractive for use in soil test labs: The variation could be significantly decreased by eliminating the effect of the unequal temperature reached in the jars during the extraction. Furthermore, the no-trap method can be carried out without using bulky mason jars, and all the material used is designed for laboratory use and doesnÕt need to be adapted for this analysis. The advantages and disadvantages of the new method are summarized in Table 1.

Comparison of Methods in the field

The modified soil amino sugar test method was compared to numerous other soil tests including preplant soil nitrate, presidedress soil nitrate, anaerobic incubation, aerobic incubation, hot potassium chloride, soil carbon dioxide evolution, crop N uptake, total soil N and total soil carbon (Results described in talk). The modified soil amino sugar test was comparable to total
Table 1. Advantages and disadvantages of the no-trap method compared to the diffusion method.

Advantages	Disadvantages
Much less lab space required More samples can be analyzed at a time No easily spilled solution in Petri dishes needed Temperature can be controlled more easily Lower variation between subsamples Material needed is designed for lab use No adaptation of material needed Vials do not break during analysis	Solution has to be filtered Ammonium-N determination cannot be done by titration Strong acid needed to lower pH DoesnÕt allow for ^{15}N analysis DoesnÕt allow for determination of exchangeable ammonium, due to formation of precipitate

soil N predicting approximately 70% of the observed variation in crop N uptake. Two independent commercial laboratories tested the modified soil amino sugar test and produced comparable results to each other and were within 5% of the values determined by our analysis. Our soil amino sugar test results for California agriculture soils indicate that a value of 100 ppm amino sugars predicted fertilizer N response in contrast to 220 ppm for Midwestern studies. This discrepancy is likely related to California agricultural soils containing less than half of the total soil N and C than Midwestern soils. The product of this research will enable soil test labs and agriculture professionals to provide additional information to growers determine whether crops would be responsive to N fertilizer applications and to fine tune application rates. The modified soil amino sugar test was better than most soil N tests at predicting crop N uptake, however, it was no better in its predictive value than total soil N.

References

Bundy, L.G., and T.W. Andrasky. 1993. Soil and plant nitrogen availability tests for corn following alfalfa. Journal of Production in Agriculture 6:200-206.

Khan, S.A., R.L. Mulvaney, and R.G. Hoeft. 2000. Direct-diffusion methods for inorganic-nitrogen analysis of soil. Soil Science Society of America Journal 64:1083-1089.

Khan, S.A., R.L. Mulvaney, and R.G. Hoeft. 2001. A simple soil test for detecting sites that are nonresponsive to nitrogen fertilization. Soil Science Society of America Journal 65:1751-1760.

Krusekopf, H. H., J. P. Mitchell, T. K.Hartz 2002. Pre-sidedress soil nitrate testing identifies processing tomato fields not requiring sidedress N fertilizer. Hortscience 37: 520-524.

Magdoff, F.R. 1991. Understanding the Magdoff pre-sidedress nitrate test for corn. Journal of Production Agriculture 4:297-305.

Mineralization of Nitrogen in Liquid and Solid Dairy Manures Applied to Soil

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Introduction

California leads the US in dairy production, with over 1.7 million lactating cows producing 21% of the nation's total milk supply in 2005. The San Joaquin Valley, where over 73% of California's dairy cows are located, is the heart of the state's milk production. In the valley, most dairies are confinement style operations, with livestock in barns and corrals year round. Most manure -- in both liquid and solid form -- is recycled to adjoining irrigated forage cropland. Recycling the immense quantity of manure generated in an environmentally sound manner is a challenge.

New regulations implemented by the Central Valley Regional Water Quality Control Board in May 2007 require that dairies create a nutrient management plan that will track the quantity of manure generated and its application to surrounding cropland. However, for dairy farmers to properly account for their nutrients and maximize crop yields, they must have a better understanding of appropriate application rates and timing.

Fresh dairy manure is composed of three components: undigested or partially digested feed (10-40%), metabolic wastes including whole and lysed bacterial cells (50-85%), and endogenous substances such as colonic cells (10-15%) (Van Soest, 1994). However, dairies such as those in the Central Valley produce a variety of manure-containing wastes with different compositions and potentially different behaviors once applied to land. We report here results of research intends to increase understanding of the composition and N mineralization potential of various dairy wastes.

Materials and Methods

Forty-six samples of solid, semi-solid, and liquid waste were collected from eight commercial milk cow dairies in Stanislaus, San Joaquin, and Sacramento Counties. Samples were comprised of fresh manure (FM), corral scrapings (CS), coarse solids removed from the liquid waste stream by screens (SM), manure composted in turned windrows (Compost), lagoon water (LW), and sludge (SL). LW and SL samples were collected, respectively, from near the surface and near the bottom of dairy wastewater anaerobic retention ponds. All samples were analyzed shortly after collection for total N (combustion for semi-solid and solid, and Kjeldahl for lagoon water), total C by combustion, total inorganic N (NH_4 and NO_3), dry matter (DM), and ash (volatile solids, VS), pH, and electrical conductivity (EC).

Three replicates of manure-amended soil and soil-only controls were prepared for destructive NH_4 and NO_3 sampling at 0, 1, 3, 6, 9, and 12 weeks. Each container received 80 g of an air-dried soil-sand mix (20:80 fine sandy loam and quartz sand) and approximately 0.2 mg of total manure N g^{-1} soil/sand mix, equivalent to 530 kg N ha^{-1}. Manure was weighed directly into each container and thoroughly incorporated. Deionized water was added to bring soils to 50% of water holding capacity. For the LW treatment, the quantity of LW added to the incubation containers was limited to that required to bring the soil water content to 50% WHC. The

resulting additions of TN ranging from 1.8 to 8.1 mg TN (vs. 16 mg for other materials) and 0.2 to 2.0 mg of organic N. All cntainers were incubated in the laboratory at 22 ^{o}C (72 ^{o}F)**Results**
Manure composition is shown in Table 1, the course of mineralization is shown in Fig. 1, and net N mineralization at the end of 12 weeks is shown in Table 2. In the manure-amended treatments, NH_4 was the dominant form of mineral N at the beginning of the incubation, but it quickly declined to very low levels, and discontinued measurement of NH_4 after week 6. Fresh Manure (FM)

Fresh manure (FM) samples were collected shortly after excretion onto paved surfaces in freestall barns. Care was taken to collect fecal matter only. In general, the physical and chemical composition varied little among dairies (Table 1).

FM from the eight dairies exhibited similar N mineralization patterns, initially immobilizing N for approximately six weeks followed by net mineralization (Fig. 1a1, 1a2). After 12 wk, approximately 13 % of the added organic N was mineralized, and the mineralization curves indicate that additional N may mineralize beyond 12 wk.

Screened Manure (SM)

Fresh manure is typically removed several times a day by flushing concrete freestall barn and milking parlor floors with large quantities of water. In many dairies, this flush water passes through mechanical screens to remove coarse particles -- usually >2 mm. This material (SM) consists mainly of bedding and undigested or partially digested feed, while suspended and dissolved materials pass through the screen.

Physical and chemical characteristics of SM varied little among dairies (Table 1) except for the sample from Dairy 6, which differed in total and organic N content. The physical appearance of this sample was much different than the other SM, having a greater proportion of smaller particles. This was likely due to a difference in the type and operation of the mechanical screens at this dairy rather than variation in diet, etc.

All SM immobilized added N. Even after 12 wk, two of the SM materials continued to show net immobilization (Fig. 1c). Immobilization was so great for these 2 samples that all soil N was immobilized (i.e. no nitrate in extractions from week 3 on). SM from Dairy 6 behaved much differently from other dairy SM. It had more than twice the total inorganic N concentration and had a lower TC content, resulting in a lower TC:TN ratio than the other SM. As a result, microbes may not have been as N-limited.

Corral Scrapings (CS)

Corral scrapings (CS) consist of urine and feces deposited in open corral areas and have undergone some degree of decomposition. We collected this material directly from corral floors rather than from stacks. Thi material was highly variable in physical appearance, moisture content, and possibly age, and the compositional data reflect these differences (Table 1). The presence of urine and evaporative concentration of salts may account for the high EC and pH of CS compared to the other materials. Soil collected with some CS samples could account for the lower volatile solids (VS) content compared to other materials.

CS from all dairies exhibited net organic N mineralization by 12 wk (Table 2). CS immobilized N between wks 1-6, followed by net mineralization (Fig. 1b1, 1b2). N mineralization appeared complete after week 9, with little or no change in inorganic N concentrations. Dairy 5 CS showed a markedly different pattern, immobilizing N between week 1 and 9, followed by slight net N mineralization. Prior to sampling at Dairy 5, the “fresher” material in the corrals had been removed, leaving behind a soil/CS mix that probably represented an older, more degraded material.

Compost

The compost consists of manure composted in turned windrows. The starting material for the composts consisted of either corral scrapings (CS), screened manure (SM), or settling basin solids. The “maturity” of the composts differed, with samples taken from “finished” and “young” compost.

N mineralization was variable for the soil amended with composts. The two b older, “mature” composts exhibited no immobilization and after 12 wk showed a small net mineralization (Fig. 1d). The “young” composts showed strong net immobilization for 6-8 wk but eventually showed net mineralization.

Sludge (SL)

Dairy lagoon sludge (SL) is composed of settled solids at or near the bottom of anaerobic storage ponds. SL was collected as deep as could be sampled (up to 5 m), and for all dairies except one, we believe we were able to sample to the bottom of the ponds. SL was highly variable in physical appearance and in residence time in the ponds, as reported to us by the cooperating dairy producers. Several samples had the consistency and smoothness of a chocolate mousse with few visible plant fibers, while others contained large, distinct plant fibers. This variability is likely due to differences in the flush water pretreatment systems (e.g., presence of mechanical screens or settling basins), size and layout of the ponds, location of inlets and outlets, and operating conditions (e.g., use of aerators, loading rates, residence time). SL age, defined as the interval since last sludge removal, ranged from ~2 to 23 years. In some cases during sampling, we did not encounter a distinct sludge layer, while in others, sludge was collected several meters below the top of a consolidated sludge layer.

Dry matter and inorganic N content (mainly NH_4) for SL from different dairies was generally similar, and large standard deviations for these characteristics (Table 1) are due to a sample from one dairy that differed greatly from the others.

SL exhibited net organic N mineralization after 12 wk (Table 2). Most SL-amended samples immobilized N in the first week but by week 3 had shown net mineralization. After week 3, little or no additional N was mineralized (Fig. 1e1, 1e2). SL from Dairy 1 showed a different pattern, with ~40% of added organic N mineralized compared to 4-17% for the other SL-amended treatments. The difference may be related to the higher NH_4 concentration from Dairy 1.

Lagoon Water (LW)

Lagoon water (LW) is dairy wastewater from anaerobic storage ponds. This wastewater is continually reused to flush freestall barns and other concrete-floored areas such as milking facility aprons, and feed lanes in corrals but is eventually transferred to crop fields during irrigation events. Mechanical screens and settling basins are used on many dairies to remove coarse particles before the wastewater enters the pond. Small particulate matter and dissolved C and N enter the ponds where they either settle to the bottom or are anaerobically decomposed. The high waste strength of these ponds results in a very thin aerobic layer (<50 cm), and the contribution of aerobic bacteria to overall waste degradation is insignificant (Zhang, 2001).

All LW samples exhibited net N immobilization after 12 wk (Fig. 1f1, Fig. 1f2). After the first week, inorganic N levels were relatively stable.

The large fraction of C mineralized (88% average, data not shown) suggest s that a large fraction of the organic N would also have been mineralized over 12 wk. Loss of N from soil by NH_3 volatilization was <1% of the total NH_4 added (acid trap data – not shown). It is conceivable that inorganic N generated by mineralization was lost by denitrification. Measurements recently made in our laboratory indicate that denitrification in the LW-amended treatments is small. This is consistent with the findings of Calderon et al. (2004). In an aerobic soil-incubation study using 107 dairy manure samples, they found that average denitrification N losses were <5% of added manure N. Further research is needed, but it appears now that LW nitrogen is immobilized by microbial activity -- perhaps stimulated by plentiful labile C compounds present in LW.

Discussion

Materials of the same type (corral, sludge, etc.) from different dairies generally produced similar mineralization patterns, and this provides hope that useful recommendations for land application rates and timing can be developed. The wide variability in composition within a category (Table 1) highlights the need for regular manure analysis. Although N mineralization may be generalized for a given manure category (e.g. ~8% of added organic N in CS is predicted to mineralize over 12 wks), this cannot be done with the composition.

The materials most commonly applied to land by dairy farmers are CS, compost, LW, and SL. FM and SM are not usually applied to dairy cropland in the Central Valley of California. Our results suggest that composts do not contribute much N to soil through mineralization during the first few months and thus do not significantly contribute to crop N requirements in the short term. But, compost does contribute organic matter necessary to maintenance of soil quality, and compost N contributes to crop N uptake over the long term. High concentrations of inorganic N (ammonium) in CS and SL coupled with net organic N mineralization make these materials valuable fertilizers during the growing season immediately following application.

Results for LW – with very high initial NH_4 content and lack of net mineralization -- suggest that it could be treated as an inorganic fertilizer when calculating short-term fertilizer N application rates. Preliminary results in our laboratory and research by others indicate that b denitrification is not a significant loss pathway; but N may be immobilized in microbial biomass. However the implication of this for N mineralization over the long term is not known.Even though conditions in the laboratory do not represent the variability of the field environment, the type of data reported here provide useful comparisons and give some idea of the manure application rates and timing that would meet crop N requirements and limit nutrient leaching. However, we recognize that manure sampling procedures (obtaining a representative sample) and the accuracy of the laboratory results are also a critical part of good manure management.

Acknowledgments

This research was supported by a grant from the Kearney Foundation of Soil Science. We thank Deanne Meyer, Ruihang Zhang,Tad Doane, Daniel Geisseler, Jiayou Deng, and Sage Sudbury for their technical assistance. We also thank the cooperating farmers who provided access to their dairy facilities and gave us many valuable insights into their waste management practices.

References

Calderon, F.J., G.W. McCarty, Jo Ann S. Van Kessel, and James B. Reeves III, 2004. Carbon and nitrogen dynamics during incubation of manured soil. Soil Science Society of America Journal 68:1592-1599.

Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant. 2nd ed. Cornell University Press, Ithaca, NY.
Zhang, R. 2001, Biology and engineering of animal wastewater lagoons. California Plant and Soil Conference, California Chapter of American Society of Agronomy.

Table 1. Composition of collected manure samples (average ± standard deviation)

Material	n	pH	EC	%DM	% VS of DM	TC mg C/g DM	TC mg C/g VS
LW	8	7.6 ± 0.2	6.1 ± 2.8	0.5 ± 0.2	48.5 ± 1.6	232.8 ± 16.9	480.2 ± 39.6
SL	11	7.9 ± 0.4	2.4 ± 1.2	16.0 ± 10.3	50.5 ± 13.9	270.3 ± 72.6	539.8 ± 39.4
FM	8	7.1 ± 0.4	3.2 ± 0.7	15.3 ± 1.0	83.4 ± 4.5	423.2 ± 23.6	507.4 ± 7.9
CS	8	8.9 ± 0.4	7.6 ± 3.9	59.7 ± 23.2	46.2 ± 18.8	238.3 ± 89.8	527.3 ± 47.3
SM	4	8.3 ± 0.3	2.1 ± 0.8	18.6 ± 5.2	87.8 ± 5.4	423.5 ± 37.2	481.6 ± 16.0
Compost	7	8.2 ± 1.0	3.0 ± 2.6	61.3 ± 28.4	57.5 ± 21.9	305.7 ± 114.2	530.2 ± 23.7

Material	n	TN, mg N/g DM	T inorgN mg N/g DM	Org N, mg N/g DM	mg Org N/g VS	TC:TN	TC:Org N
LW	8	89.5 ± 15.5	61.0 ± 14.6	28.5 ± 3.0	58.8 ± 7.2	2.6 ± 0.4	8.3 ± 1.3
SL	11	29.6 ± 9.2	4.7 ± 4.2	24.8 ± 6.8	49.7 ± 5.7	9.3 ± 1.1	10.9 ± 0.9
FM	8	25.2 ± 3.3	1.9 ± 1.2	23.3 ± 2.3	28.0 ± 2.6	17.0 ± 1.9	18.2 ± 1.4
CS	8	19.3 ± 6.8	1.0 ± 0.8	18.3 ± 7.3	40.7 ± 6.8	12.2 ± 1.4	13.2 ± 2.0
SM	4	17.4 ± 5.5	2.2 ± 1.1	15.2 ± 4.4	17.6 ± 6.3	26.2 ± 8.4	29.8 ± 9.2
Compost	7	22.3 ± 6.8	0.9 ± 0.7	21.7 ± 6.6	38.9 ± 7.5	13.6 ± 2.5	14.0 ± 2.5

Fig. 1. Net N mineralization (NH_4 + NO_3) over 12 wks. Net mineralization was calculated by first subtracting control soil inorganic N from each material for each sampling date then subtracting wk 0 inorganic N concentration from amended soils for each sampling date. Error bars represent the standard error of three replicates.

Session VI

Food Safety

Session Chairs:

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Joe Voth, Grimmway Farms

Fate of Pathogens in the Environment and Implications in the Primary Production Chain of Fresh Produce

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The Centers for Disease Control estimate that foodborne illness in the United States accounts for 76 million cases with 325,000 hospitalizations and 5,000 associated deaths each year. The USDA Economic Research Service (ERS) estimates that the annual economic costs incurred from five major pathogens- *E. coli* O157:H7, other STEC, *Campylobacter* spp., *Listeria monocytogenes*, and *Salmonella spp*.- are approximately $6.9 billion. Cow manure has been associated with pathogenic bacteria such as *E. coli* O157:H7, other STEC, *Campylobacter spp*., *Listeria monocytogenes*, and *Salmonella spp*, etc and crops fertilized with this materials may transmit these pathogens to the consumers. Furthermore, waste lagoons and holding ponds can impair air quality via the release of odorous compounds, leading to nuisance complaints as well as leaching of nutrients and potential pathogens to groundwater. In the Santa Ana River watershed, the problem of impaired air quality is nothing new, and contamination of surface water and groundwater is still under investigations to determine sources. Results from these studies are applicable to any part of California where there is close proximities between livestock and crop production. The goal of this study was to quantify the sources, patterns of concentrations and fluxes of FIB (i.e. *Escherichia coli (E. coli*), enterococci., total coliforms) and *E. coli* O157:H7 from representative land use types in middle Santa Ana River Watershed region. To achieve these goals, bacterial concentrations were measured over a fifteen month period with different land use types from seventeen sites through 2004-05. A survey of the creeks and channels revealed the highest abundance of *E. coli* in sediment compared to surface water. Higher concentrations of *E. coli* (up to 4.5 x 10^6 CFU/g of sediment) or (up to 2.3 x 10^5 CFU/100 ml of water) were observed in the creeks and channels compared to less than 1.6 x 10^2 in the control sites and effluent from waste water treatment plants. The total *E. coli* O157 concentrations and other fecal bacteria in different matrices from some of the sites in the watershed were also determined. The numbers of presumptive *E. coli* O157 in the samples ranged from 250 CFU/g of sediment to130 CFU/100 ml of water. These numbers were observed along channels which are highly impacted by agricultural activities compared to less than 10 CFU/g of sediment and undetectable level in surface water in areas impacted by urban runoff. To evaluate the effects of sites on the concentrations of *E. coli* O157 samples were grouped and mean separation was carried out by the least-significant-difference (LSD) test. The concentrations of *E. coli* O157 were significantly different between both channels. On the average, the highest concentration of *E. coli* O157 was recorded in December 2004 and the lowest in June 2005 at all the sampling points in the watershed. All isolates were characterized by pulse field gel electrophoresis using XbaI restriction endonucleases. Most of the restriction endonuclease digestion profiles were spatially and temporally clustered, and most of the clusters were indigenous to specific sources. Within the study area, *E. coli* O157 subtypes were present in small numbers but with more frequency among locations near agricultural activities with bovine impact than locations with none-bovine impact. Therefore, the presence of pathogens such as *E. coli* O157:H7 in very small numbers in sediment and surface water may result in the contamination of groundwater or produce if the water is used to irrigate crops. Our laboratory studies have shown that when produce are grown in soil contaminated with *E. coli* O157:H7 the pathogen will survive in soil for more than 90 days and may also survive on plant surfaces for more than 25 days.

Food Safety and the Environment: Exploring How Food Safety Concerns are Impacting Grower Efforts to Protect the Environment

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Excerpts from *A Grower Survey: Reconciling Food Safety and Environmental Protection* (RCDMC 2007). This full report is available at www.rcdmonterey.org.

INTRODUCTION

California is a global leader in agricultural production and economic strength, and has some of the world's most expensive land. In addition, the Central Coast of California boasts some of the highest concentrations of biologic diversity in the world. Providing safe, quality produce to consumers is the number one priority for the produce industry. Since the 1990's, the issue of food safety has increased in importance, especially with respect to outbreaks of *E. coli* O157:H7 associated with leafy greens (e.g. lettuce, spinach, etc...). Simultaneously, agricultural producers face increasing environmental demands and have taken a proactive approach to voluntarily improve water quality on the Central Coast of California. The efforts of agricultural producers on the Central Coast and throughout the state to protect water quality and the environment may be compromised as some food safety guidelines, or interpretation thereof appear to be in conflict with management practices intended to improve water quality and enhance natural habitat. Growers of fresh produce, particularly leafy greens, are caught in the middle between these competing priorities and in many cases are being put in a position of having to choose between being able to sell their crops or protect the environment.

In response to grower concerns over this mounting conflict between food safety and environmental protections, the Resource Conservation District of Monterey County (RCD) conducted a survey of more than 600 irrigated row crop growers on the Central Coast. The survey was co-sponsored by the Grower-Shipper Association of Central California, Central Coast Agriculture Water Quality Coalition, and the Monterey County Agricultural Commissioner's Office. The purpose of the grower survey was to better understand the impacts of the conflict and guide efforts to reconcile conflicting demands for food safety and environmental protection being placed on Central Coast growers. The survey was conducted in the spring of 2007 and this report shares the most significant results.

SURVEY INFORMATION

Growers of row-crops were the target of the survey. The survey was mailed out to 600 Central Coast row-crop growers in the spring of 2007 using the Regional Water Quality Control Board (Region 3) Ag Waiver mailing list. These growers had operations in Monterey, San Benito,

2008 Poster Abstracts

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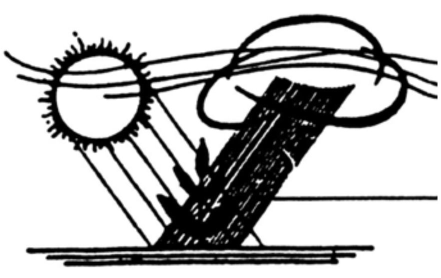

Reducing Off-site Movement of Sediment and Pesticides in Drainage Waters

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Growers in Southern California are under continuous pressure to conserve water to meet the growing demands in urban areas and to improve the quality of drainage waters discharged into waterways. The quality of drainage waters discharged into waterways in California is regulated under California Water Code Section 13260 and Federal Clean Water Act. To assist growers in complying with current water quality regulations with regard to sediment and the expected regulations with regard to pesticides, we evaluated the impact of several on-farm irrigation and insecticides management practices on water conservation and drainage water quality.

The study was conducted on two alfalfa fields at the University of California Desert Research and Extension Center near Holtville, California. The alfalfa fields were irrigated by surface irrigation systems (border and furrow irrigation). Five irrigation/insecticides (Chlorpyrifos-Lorspan 4E) application practices (irrigation events 1-11 days after insecticide applications) were implemented on the furrow-irrigated alfalfa field. Three irrigation/insecticides (Chlorpyrifos-Lorsban 4E, SEVIN brand 80S, and Beta-Cyfluthrin) treatments were implemented on the border-irrigated alfalfa field (irrigation events 1 day after insecticides applications). Irrigation application efficiency measures and insecticide and sediment concentrations in runoff water were determined for the various treatments. Both sediment load and concentration in runoff water generated from the border-irrigated field was approximately 1/6 to 1/3 of that of the furrow-irrigated field. Pesticide concentrations in runoff water were reduced by 68% when irrigation events occurred 4 days after insecticide applications as compared to irrigation events 1 day after application. Water use efficiency and water quality indicators (sediment and pesticides) in border-irrigated alfalfa fields are significantly higher than those of furrow-irrigated fields.

Low Residue Cover Crops for Fallow Vegetable Fields on the Central Coast

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Winter cover crops in Salinas Valley vegetable rotations help to address both production and environmental issues. Cover crops help to manage leaching of nitrate by absorbing 65-70% of residual nitrate from the soil. The nitrate is incorporated into cover crop biomass and becomes incorporated into the soil organic matter where it is less likely to leach and becomes available for later crop growth as organic matter mineralizes. Cover crops also reduce sediment losses by 76 - 84% compared to uncover cropped fields. In spite of the benefits of growing winter cover crops, the reality is that they are difficult to schedule into rotations given that cover crops tie up high rent land; also cover crops increase the risk of missing planting schedules in the spring if rains preclude opportunities to incorporate them into the soil in a timely manner. For these and other reasons, winter cover crop use in the Salinas Valley probably comprises no more than 5% of the acreage. In order to find cover crop strategies that could be included into vegetable rotations, we examined a low-residue cover crop ('Trios 102' triticale) grown on the furrow bottom. 'Trios 102'is winter dormant and grows enough to cover the furrow bottom, but does not cause a residue problem in the spring that would impede bed shaping and planting. Low-residue, furrow-bottom cover crops produced only 0.29 to 0.82 T/A of biomass in 2006 and 2007, respectively, but reduced sediment loss by 50% compared with the winter fallow treatment. Given the need for practices that can improve the quality of water leaving production fields, it appears that low-residue, furrow-bottom cover crops provide a useful and practical option for reducing sediment and nutrient losses.

Early-Season Pest Control in Cotton: Good or Bad?

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Systemic insecticides, applied at planting have been the standards for early-season control of spider mites and aphids on cotton. These same insecticides also suppress thrips that are considered beneficial from their reported feeding on spider mite eggs. In seasons characterized by cooler spring conditions, the presence of thrips can cause reductions in leaf area, terminal damage and even early square loss. This damage occurs with or with out the presence of spider mite eggs as an alternative food source. Plants protected with systemic insecticide experience damage from foraging thrips. The influx of migrating thrips that have to consume enough plant material before feeding is controlled can overwhelm the protective systemic option. Handling of systemic insecticides has become a worker safety concern that requires special monitoring of employees and added costs.

New seed treatments are becoming available as alternatives to the standard systemic materials. The results of a field trial comparing early-season control of cotton pests by new seed treatments to old standards will be presented. Our data shows that thrip damage can be reduced by chemical treatments and that final lint yields are not always directly related to early damage. A successfully integrated approach requires season long attention including mid-season lygus control that also influenced our field results.

Influence of Amendments on Unsaturated Hydraulic Conductivity of Saline-Sodic Soils

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Re-use of saline-sodic drainage water (DW) for the irrigation of salt tolerant forages and row crops is an important tool for salinity and drainage management on the Westside San Joaquin Valley of California. The sodic nature of this DW can cause clay dispersion and reduce infiltration and the hydraulic conductivity of soil. Proper irrigation management and on-going soil reclamation are needed to ensure the sustainability of these DW re-use systems, now called Integrated On-Farm Drainage Management (IFDM). The objectives of this study are to characterize the unsaturated hydraulic conductivity of soil from three stages of the IFDM at Red Rock Ranch and assess the reclamation potential of gypsum, sulfur, and poultry manure when applied at very high rates. Soils in Stage 1 are freshwater-irrigated while those in Stages 3 and 4 are highly dispersed due to 7 years of continuous irrigation with DW averaging 12 and 13 dS/m ECw, respectively. A split plot design was used with soil amendment as the main plot factor and salinity (0.5 dS/m, 6 dS/m, and 12 dS/m) of the infiltrating water as the sub-plot factor. Gypsum and poultry manure were applied twice yearly at 10 ton/acre and sulfur at 2 ton/acre per application. The treatments (including non-amended control) were assigned to 1 m^2 plots and replicated three times. Infiltration is measured twice a year with Decagon "mini-disk infiltrometers" at three suctions (0.5, 2 and 6 cm) which represent different soil tensions. Unsaturated hydraulic conductivity data for Stage 4 soil following two rounds of amendment application will be presented.

Interaction of Nitrogen Rates and AirJection® Irrigation on Organic Broccoli Production

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Evaluating the impact of air via subsurface drip irrigation (SDI) system, referred to as AirJection® Irrigation, has been the focus of our research in organic vegetables. Our major objective has been to assess the impact of four Nitrogen (N) rates on the yield and quality of organic vegetable crops when subjected to AirJection® irrigation. Work conducted in summer 2007, with organically grown Bell peppers, revealed that in contrast to the N rate effects, which had significant ($P<0.05$) increases in overall yield, there were no significant yield increases due to AirJection® Irrigation. However, AirJection® Irrigation appeared to influence early bloom, early fruit maturity and extended fruiting. Both AirJection® Irrigation and N rate had significant effect ($P<0.05$) on nitrate uptake, transpiration rate and water use efficiency (WUE). We are now continuing the research with organically grown cool season Broccoli on beds that are 5ft wide and 50ft long. The experiment is a split plot design comprising of 8beds representing 4 replications of air-injected and no-air treatments (control) as the main treatment, and N rates as subplot treatment. Four rates of N (30, 60, 90 and 120 lbs/acre) were applied as commercially available organic fertilizer (12-0-0) derived from feather meal. Currently, the crop has been established and a number of soil and plant characteristics are being monitored. For example, at 33 days after transplanting (DAT), both AirJection® Irrigation and N rate had a significant effect ($P<0.05$) on transpiration rate. Nitrogen rate had a significant effect ($P<0.05$) on stomatal conductance and WUE. Tissue analyses and additional photosynthesis, transpiration rates, WUE, and in-situ soil respiration measurements have been conducted. Yield and plant biomass data will be determined after harvest.

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