American Society of Agronomy
California Chapter

Co-sponsored by the California Plant Health Association

2011
CONFERENCE PROCEEDINGS

Agricultural Certification Programs-Opportunities and Challenges

February 1 & 2, 2011

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CALIFORNIA PLANT & SOIL CONFERENCE
AGRICULTURAL CERTIFICATION PROGRAMS-
OPPORTUNITIES AND CHALLENGES

TUESDAY, FEBRUARY 1, 2011

10:00 **General Session Introduction** – Session Chair & Chapter President – Larry Schwankl, UC Cooperative Extension

10:10 Food Marketing and Distribution Trends: Buyers Require More Services from Suppliers —Roberta Cook, UC Davis

10:40 The Evolving Certification Landscape —Dan Sonke, Sureharvest

11:10 Utilizing Third Party Provider Services—Tim York, President of Markon Cooperative

11:40 Discussion

12:00 **Lunch - Opportunity to Network with Colleagues and Friends**

CONCURRENT SESSIONS (PM)

I. Nutrient Management

1:30 Introduction - Session Chairs: Sharon Benes and Joe Fabry

1:35 **Understanding and Correcting Plant Nutrition in Tree Crops**—Bob Beede, UC Cooperative Extension, Tulare Co.

2:00 **Foliar Fertilization of Stone Fruit- Zn, B, and Ca**—Scott Johnson, UC Cooperative Extension Kearney Agricultural Center

2:25 **Potassium Nutrition of Winegrapes**—Stuart Pettygrove, Department of Land, Air and Water Resources, UC Davis

2:50 Discussion

3:00 BREAK

3:20 **Improving Nitrogen Use Efficiency in Lettuce Production**—Richard Smith, UC Cooperative Extension, Monterey Co

3:45 **How to Read a Soil Test Report**—Dan Munk, UC Cooperative Extension, Fresno Co.

4:10 **How to Read a Tissue Test Report**—Gary Weinberger, Consultant, Weinberger & Assoc., Hanford, CA.

4:35 Discussion

4:45 **ADJOURN**

II. Soil Salinity and Quality

1:30 Introduction – Session Chairs: Steve Grattan and Joe Fabry.

1:35 **Managing Salts in the Central Valley**—Daniel Cozad, Central Valley Salinity Coalition

2:00 **Re-evaluation of Soil Salinity Leaching Fraction Requirements**—John Letey, Professor Emeritus UC Riverside, Former Director of UC Salinity-Drainage Task Force

2:25 **Assessing the Suitability of Water for Irrigation**—Don Suarez, Director, USDA-Agriculture Research Service, Salinity Laboratory

2:50 Discussion

3:00 BREAK

3:20 **Research on Soil Quality in California: Processes, Justification and Long-term Benefits**—Louise Jackson, Land Air Water Resources, UC Davis

3:45 **New Soil Survey Applications to Investigate California's Soil Resource**—Toby O'Geen, Department of Land, Air and Water Resources, UC Davis

4:10 **Understanding the Fate of Antibiotics in Concentrated Animal Feeding Operations** —Sanjai Parikh, Department of Land, Air and Water Resources, UC Davis

4:35 Discussion

4:45 **ADJOURN**

ADJOURN to a Wine and Cheese Reception *in the Poster Room.*
A complimentary drink coupon is included in your registration packet

WEDNESDAY, FEBRUARY 2, 2011 – CONCURRENT SESSIONS (AM)

III. Water Management

8:30 **Introduction** – Session Chairs: Danyal Kasplagil, Allan Fulton

8:35 **Irrigation Management in Alfalfa When Water Supplies are Sufficient**—Blaine Hanson, Irrigation and Drainage Specialist, Department of Land, Air and Water Resources, UC Davis

9:00 **The Role of Regulated Deficit Irrigation in Alfalfa when Water Supplies are Limited**—Blaine Hanson, UC Davis

9:25 **Deficit Irrigation Strategies for Sorghum**—Bob Hutmacher, Extension Cotton Specialist, Dept of Plant Sciences, UC Davis

9:50 Discussion

10:00 BREAK

10:20 **Irrigation Management in Almonds When Water Supplies are Limited**—Ken Shackel, Professor/Pomologist, Department of Plant Sciences, UC Davis

10:45 **Impacts of Irrigation and Pruning on Canopy Management and Potential Productivity in Walnut**—Bruce Lampinen, Extension Specialist, Department of Plant Sciences, UC Davis

11:10 **Trends in Irrigation Pumping Plant Efficiency and Management Responses**—Peter Canessa, Center for Irrigation Technology, Cal State University Fresno

11:25 Discussion

IV. Ag Certification Systems

8:30 **Introduction** – Session Chairs: **Lori Berger,** CA Specialty Crops Council and **Mary Bianchi, UCCE**

8:35 **Seed Certification Programs, an Historical Perspective on the Value of Certification**—Larry Teuber, UC Davis, Executive Director California Crop Improvement Association

9:00 **Almond Board of California** Sustainability—Bob Curtis, Almond Board of California

9:25 **Certifying for Markets and Compliance**—Mike Villaneva, Technical Director, California Leafy Green Products Handler/Marketing Agreement

9:50 Discussion

10:00 BREAK

10:20 **Improving Nutrient Management: The Role of CCA's**—Rob Mikkelson, International Plant Nutrition Institute

10:45 **The Value and Use of an Accredited Agronomist**—Nathan Heeringa, Innovative Ag Services, LLC

11:10 **When Certification and Compliance Collide: Co-management of Food Safety and Water Quality**—Karen Lowell

11:25 Discussion

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

CONCURRENT SESSIONS (PM)

V. Dairy Issues

1:30 **Introduction** – Session Chairs: Larry Schwankl, Brook Gale, Nathan Heeringa

1:35 **Identifying and Mitigating VOC Emissions on Dairy Facilities**—Frank Mitloehner, Cooperative Extension Specialist, UC Davis

2:00 **Study On Harvested Crop Residue: Sampling Protocol for Nutrients**—Jennifer Hegey, UCCE Stanislaus County

2:25 **Use of Linear Move/Center Pivots with Manure Water**—Charles Van Der Kooi, Van Der Kooi Dairy

2:50 Discussion

3:00 **BREAK**

3:20 **Report Card on Nutrient & Waste Management Plan Submissions: How They Affect Management in the Field**—*To be determined*, Central Valley RWQCB

3:45 **Adoption of Nutrient Management, Conservation Tillage and Manure Application Technology in the Dairy Industry**—Ladi Asgill, Sustainable Conservation

4:10 **Laboratory results from the RWQCB monitoring requirements on dairy facilities**—Joe Mullinax, Denele Analytical.

4:35 **Discussion and ADJOURN**

VI. Environmental Quality

1:30 **Introduction** – Session Chairs: Rodrigo Krugner, Brad Hanson, Brook Gale, Matt Fossen

1:35 **Postharvest Fumigation of Specialty Crops—Spencer Walse**—USDA-Agriculture Research Services

2:00 **Pesticide Detection and Regulations Related to Surface Water Quality**—Parry Klassen, Coalition for Urban/Rural Environmental Stewardship

2:25 **Pesticide Exposure and Toxicology**—Bob Krieger, UC Riverside

2:50 Discussion

3:00 **BREAK**

3:20 **Agricultural Dust Contributions to Air Quality Issues**—Ross Baderscher / James Sweet, San Joaquin Valley Air Resources Board

3:45 **Groundwater Nitrate in the Tulare Lake Basin and Salinas Valley**—Thomas Harter, Department of Land, Air and Water Resources, UC Davis

4:10 **Reducing Volatile Organic Compound Emissions from Pesticides by Switching Formulations**—Pam Wofford, CA Dept of Pesticide Regulation

4:35 **Discussion and ADJOURN**

Table of Contents

PAST PRESIDENTS

YEAR	PRESIDENT	YEAR	PRESIDENT
1972	Duane S. Mikkelsen	2010	Larry Schwankl
1973	Iver Johnson		
1974	Parker E. Pratt		
1975	Malcolm H. McVickar		
1975	Oscar E. Lorenz		
1976	Donald L. Smith		
1977	R. Merton Love		
1978	Stephen T. Cockerham		
1979	Roy L. Branson		
1980	George R. Hawkes		
1981	Harry P. Karle		
1982	Carl Spiva		
1983	Kent Tyler		
1984	Dick Thorup		
1985	Burl Meek		
1986	G. Stuart Pettygrove		
1987	William L. Hagan		
1988	Gaylord P. Patten		
1989	Nat B. Dellavalle		
1990	Carol Frate		
1991	Dennis J. Larson		
1992	Roland D. Meyer		
1993	Albert E. Ludwick		
1994	Brock Taylor		
1995	Jim Oster		
1996	Dennis Westcot		
1997	Terry Smith		
1998	Shannon Mueller		
1999	D. William Rains		
2000	Robert Dixon		
2001	Steve Kaffka		
2003	Dave Zoldoske		
2004	Casey Walsh Cady		
2005	Ronald Brase		
2006	Bruce Roberts		
2007	Will Horwath		
2008	Ben Nydam		
2009	Tom Babb		

PAST HONOREES

YEAR	PRESIDENT	YEAR	PRESIDENT	YEAR	PRESIDENT
1973	J. Earl Coke	1995	Leslie K. Stromberg	2007	Norman MacGillivray
1974	W.B. Camp		Jack Stone		William Pruitt
1975	Milton D. Miller	1996	Henry Voss		J.D. (Jim) Oster
	Ichiro "Ike" Kawaguchi		Audy Bell	2008	V. T. Walhood
1976	Malcom H. McVickar	1997	Jolly Batcheller		Vern Marble
	Perry R. Stout		Hubert B. Cooper, Jr.		Catherine M. Grieve
1977	Henry A. Jones		Joseph Smith	2009	Dennis Wescot
1978	Warren E. Schoonover	1998	Bill Isom		Roland Meyer
1979	R. Earl Storie		George Johannessen		Nat Dellavalle
1980	Bertil A. Krantz	1999	Bill Fisher	2010	L. Peter Christensen
1981	R. L. "Lucky" Luckhardt		Bob Ball		D. William Rains
1982	R. Merton Love		Owen Rice	2011	Blaine Hanson
1983	Paul F. Knowles	2000	Don Grimes		Gene Maas
	Iver Johnson		Claude Phene		Michael Singer
1984	Hans Jenny		A.E. "Al" Ludwick		
	George R. Hawkes	2001	Cal Qualset		
1985	Albert Ulrich		James R. Rhoades		
1986	Robert M. Hagan		Carl Spiva		
1987	Oscar A. Lorenz	2002	Emmanuel Esptein		
1988	Duane S. Mikkelsen		Vince Petrucci		
1989	Donald Smith		Ken Tanji		
	F. Jack Hills	2003	Vashek Cervinka		
1990	Parker F. Pratt		Richard Rominger		
1991	Francis E. Broadbent		W. A. Williams		
	Robert D. Whiting	2004	Harry Agamalian		
	Eduardo Apodaca		Jim Brownell		
1992	Robert S. Ayers		Fred Starrh		
	Richard M. Thorup	2005	Wayne Biehler		
1993	Howard L. Carnahan		Mike Reisenauer		
	Tom W. Embelton		Charles Schaller		
	John L. Merriam	2006	John Letey, Jr.		
1994	George V. Ferry		Joseph B. Summers		
	John H. Turner				
	James T. Thorup				

American Society of Agronomy
California Chapter

2010 Chapter Board Members

Executive Committee

President	Larry Schwankl, UC Davis
First Vice President	Mary Bianchi, UCCE San Luis Obispo County
Second Vice President	Allan Fulton, UCCE Tehama County
Secretary-Treasurer	Dave Goorahoo, CSU Fresno
Past President	Joe Fabry, Fabry AG Consulting

Governing Board Members

One-year term	Sharon Benes, CSU, Fresno
	Lori Berger, California Specialty Crops Council
	Brook Gale, USDA-NRCS
Two-year term	Steve Grattan, UC Davis
	Brad Hanson, USDA-ARS
	Nathan Heeringa, Innovative Ag Services, LLC
Three-year term	Matt Fossen, CA Dept. of Pesticide Regulation
	Rodrigo Krugner, USDA Ag Research Service
	Danyal Kasapligil, Dellavalle Laboratory

CALIFORNIA CHAPTER – AMERICAN SOCIETY OF AGRONOMY
2010 ANNUAL CHAPTER BUSINESS MEETING MINUTES; February 3, 2010

1. **Call to Order, (President Joe Fabry, about 12:30 p.m.)**
   a. Welcomed attendees to 38th annual meeting of the Calif. Chapter of the ASA.
   b. Offered general remarks and reminders about the 2010 conference
   c. Acknowledged sponsorships of refreshments at breaks by:

      - Innovative Ag Services
      - Valley Tech Agricultural Services
      - CCA, per Keith Backman

   d. Introduced and thanked the volunteers serving on the Executive Committee and Governing Board

      - Past President, Tom Babb
      - 1st VP, Larry Schwankl Proceedings,
      - 2nd VP, Mary Bianchi Site Arrangements,
      - Secretary & Treasurer, Allan Fulton Registration.
      - Ben Faber, Joe Voth, Sharon Benes, Dave Goorahoo, Lori Berger, Brook Gale, Steve Grattan, Brad Hanson, and Nathan Heeringa.

   e. Introduced Past Presidents and individuals who have served on the Governing Board of the Chapter in the past.

2. **Present minutes of Business Meeting of Feb 4, 2009** (Introduction - Fabry)
   a. Read minutes of Feb 4, 2009 business meeting (Fulton)
   b. Motion made and second to accept the minutes. Passed

3. **Presentation of Scholarships to Essay Contest Winners** (Introduction – Fabry, change in agenda requested)
   a. Winners announced by Renee Pinel, scholarships sponsored by Western Plant Health Association

      - 1st place, $1000, to Caitlin Lawrence, Cal Poly San Luis Obispo
      - 2nd place, $500, to Robert Pintacsi, UC Davis

4. **Treasurer's Report** (Introduction – Fabry)
   a. Reported by Allan Fulton. Chapter balance on February 1, 2010 - $3940.25. Reflects payment of most of the 2010 Conference expenses but receipts from on-line and walk-in registrations to 2010 Conference attendees not deposited. Transactions of conference expenses and receipts in progress.
   b. Motion moved and second to approve Treasurer's report. Motion passed.

5. **Continuation of Scholarship Awards** (Introduction – Fabry)
   a. Poster Contest winners announced by Ben Faber

      - 1st place Graduate Student, $350, Shashi Yellareddygari, CSUF
      - 2nd place Graduate Student, $100, Prasa Yadavali, CSUF
      - 1st place Undergraduate Student, $350, Natalio Mendez, CSUF
      - 2nd place Undergraduate Student, Gerardo Orozco, CSUF

6. **Honorees Program –** (Introduction – Fabry/Babb)
   a. Mary Bianchi presents Honorarium to Peter Christensen
   b. Bruce Roberts presents Honorarium to Bill Rains

7. **Nomination & Election of persons to serve on Executive Committee and the Governing Board** (Fabry)
   a. Leaving Board after serving 3-year terms are: Ben Faber, Joe Voth, and Sharon Benes. Tom Babb leaves as past president;
   b. Nominations opened for the election of persons to serve on the Executive Committee and Governing Board for 2010.
   c. Board nominations for Executive Committee and Governing Board:
      i) Larry Schwankl as President
      ii) Mary Bianchi as First Vice President
      iii) Allan Fulton as Second Vice President
      iv) Dave Goorahoo as Secretary/Treasurer
      v) To serve 3 Year Terms on Board:
         - Danyal Kaspagil, Dellavalle Laboratories
         - Matt Fossen, CDPR
         - Rodrigo Krugner, USDA-ARS, Fresno
         - Sharon Benes to serve one year term as replacement for Dave Goorahoo who will be serving as Executive Secretary and Treasurer
   d. There were no other nominations from the floor
   e. A motion and second was moved to accept unanimously the Board nominations. Motioned passed.

8. **Old Business** – No old business was discussed.

9. **New Business** – No new business was discussed.

10. **Passing of the Gavel (Fabry/Schwankl)**
    a. Joe Fabry passed the Chapter gavel to new President Larry Schwankl.
    b. Schwankl presents Fabry with a plaque in appreciation for his service as Chapter President
    c. Fabry assumes role of Past President

11. **Meeting Adjourned** (**Schwankl**). In time for afternoon sessions which begin at 1:30 PM

American Society of Agronomy

California Chapter

2011 Honorees

Gene Maas
Blaine Hanson
Michael Singer

Dr Eugene Maas

Plant Physiologist, USDA Agricultural Research Service Salinity Laboratory

Dr. Eugene (Gene) Maas remains one of the most influential researchers in crop salt- tolerance. Most of his ‘claim-to-fame’ accomplishments were achieved as Plant Physiologist at the USDA/ARS Salinity Laboratory in Riverside, CA. Dr. Maas retired from his position in January 1995 and he and his wife Norma currently live in Riverside when they are not traveling the world or visiting relatives in North Dakota.

Gene Maas grew up on a farm near Jamestown, ND and earned a BS in chemistry from Jamestown College in 1958, while working part-time for the USDA Agricultural Stabilization and Conservation Service. In 1959, Dr. Maas began his career with the ARS as a part-time physical science aid while completing his MS degree in soil science at the University of Arizona. He later earned his Ph.D. in soil science at Oregon State University in 1966. Dr. Maas was awarded a National Science Foundation-National Research Council postdoctoral research associate-ship with Sterling Hendricks at the Mineral Nutrition Pioneering Research Lab in Beltsville, MD, from 1966 to 1968. He then transferred to the US Salinity Lab in 1968 and became research leader of the Plant Sciences group in 1975. In addition to being Supervisory Plant Physiologist at the US Salinity Lab, he was also an adjunct professor of plant physiology with the University of California at Riverside and an affiliate faculty member of the Department of Plant, Soil and Entomological Sciences of the University of Idaho.

Dr. Maas has authored or co-authored over 100 scientific publications including several book chapters concerning crop salt tolerance, mechanisms of ion uptake under saline conditions, interactive effects of salinity and abiotic stresses and the physiological effects of salinity. He was also instrumental in developing a mechanistic model describing plant growth and development of salt-stressed cereal crops. His work on sodium-calcium interactions and crop sensitivity at different growth stages has contributed substantially to current management strategies that allow the use of more saline water for irrigation. Dr. Maas is most widely known nationally and internationally for the development of indices for salt tolerances with colleague Glenn Hoffman. These ‘Maas-Hoffman coefficients’ are used all over the world and remain today the bases of many models, water quality standards and water policy decisions throughout the country. He has also been a mentor for many visiting scientists all over the world including postdoctoral and graduate students.

Dr Maas received the Certificate of Merit for his experiments on salt tolerance of corn grown in the organic soils in the Sacramento-San Joaquin Delta. He was a member of the ASA, SSSA, CSSA, the Western Society of Soil Science, the American Society of Plant Physiologists, and several other professional societies. He served as Associate Editor of Crop Science from 1990 to 1993. Dr. Maas has indeed had a very distinguished career in crop-salinity research and is most deserving of this California Chapter ASA award.

Blaine Hanson

Extension Irrigation and Drainage Specialist Emeritus
University of California, Davis

Blaine Hanson was raised in the Land of Enchantment or New Mexico, where he enjoyed very much the wide, open spaces and clear blue skies of southern New Mexico. He graduated from New Mexico State University in 1969 in Civil Engineering and then from Utah State University in 1971 with a MS in Civil Engineering. He then spent four years in the US Air Force, assigned most of the time at Mather Air Force Base near Sacramento, where he met and married Marlene Rice. After the Air Force, Blaine and Marlene spent an enjoyable three years at Fort Collins, Colorado where he attended graduate school at Colorado State University, graduating in 1977 with a Ph.D in Agricultural Engineering. They moved to Davis, California in 1977 where he accepted a position with the University of California Cooperative Extension as an Irrigation and Drainage Specialist in the Department of Land, Air and Water Resources.

Blaine vowed to never work in agriculture after hoeing and hand-picking cotton while in high school. However, after working in agriculture for 33 years, he retired on July 1, 2010.

Blaine's research focused primarily on the reduction of subsurface drainage water through improved irrigation, energy-efficient irrigation, reducing pesticide concentrations in surface runoff, and crop water use. Two projects were particularly notable. One project showed subsurface drip irrigation of processing tomatoes in salt-affected soil to be highly profitable compared to other irrigation methods and that subsurface drainage systems and drainage water disposal methods may not be needed under drip irrigation. A second project currently ongoing, is determining the evapotranspiration of alfalfa at various locations in California.

Blaine has published 105 peer-reviewed papers and was a co-author of 15 manuals for growers on various aspects of irrigation water management. He is a member of the honorary agriculture society Gamma Sigma Delta and was awarded the 2006 Irrigation Person of the Year by the California Irrigation Institute. A recognition award was received in 2009 from the California Tomato Growers Association for the research on drip irrigation under saline soils. A paper, coauthored with Larry Schwankl, received the Best Practices Paper Award in 2000 by the Environmental and Water Resources Institute and Drainage Council of the American Society of Civil Engineers, and in 1994 and 2009, Blue Ribbon Awards were given by the American Society of Agricultural and Biological Engineers for manuals on irrigation pumping plants and maintaining microirrigation systems.

"I have greatly enjoyed the 33 years of working for the University of California, Davis and feel that the university has been very good to me. While at times, it was hard working in hot, humid fields, it was always interesting and challenging. I am grateful for my career at UC Davis and for the association with many outstanding people. However, I am finding retirement also to be an enjoyable experience."

Michael Singer

Professor Emeritus of Soil Science and Soil Resource Scientist

Professor Michael Singer has had an accomplished career in soil science. His accomplishments in teaching, research, outreach, and administration are noteworthy and show a relentless drive to convey information and solutions to issues that impact soil resources.

Mike was born in Manhattan, New York, a place not known for producing soil scientists. His father encouraged him to pursue a career in agronomy. Mike received his B.S. in Agronomy from Cornell University. Mike continued his education at the University of Minnesota, St. Paul, receiving a M.S and PhD. in Soil Science. He was a postdoctoral scholar at the University of Washington before taking the position of Assistant Professor of Soil Science and Assistant Soil Resource Scientist in the Experiment Station at the University of California Davis in 1973. After becoming an associate professor, he quickly established his international presence in research through being awarded a Fulbright Senior Scholar at the CSIRO Division of Soils, Canberra, Australia. He took on the role of vice chairman before becoming a full professor in 1985. He later served as chairman of the Department of Land, Air and Water Resources from 2001 to 2005.

Professor Singer's research is centered on evaluating soil physical properties that control soil erodibility, in particular, rates, and processes of soil crusting and mechanisms of aggregate stabilization. A wide range of soils has been part of this interest, including agriculture, forest and range soils. He continued to branch out his research to include soil management impacts on water quality in California rangelands and urban areas. He is also especially interested in soil genesis, in particular rates and types of mineralogical change in soils over time. Magnetic minerals including magnetite and maghemite were the focus of this research for the past 20 years. His research has resulted in over 130 peer reviewed research papers, a soil science text now in its sixth edition and over 100 published abstracts. He has taught a variety of classes including Soil Science, Soil Interpretations, Field Study of Soil Resources, Soil Erosion and Conservation, and California Geography.

Mike's university and professional service accomplishments have been wide reaching. In 1991 and 1997, he received the "Excellence in Reviewing Manuscripts" award from the Soil Science Society of America. In 1995, he became a "Fellow" of the Soil Science Society of America, the highest recognition attainable in a scientific professional society. He served as president of the Soil Science Society of America in 2003. Mike served on numerous departmental and university committees during his career. His dedication to service provides an example of excellence in citizenship and leadership. `

After life at the university, Mike continues leading as the president of the Hillel House in Davis. Mike's career has been selfless and characterized by giving through knowledge and hard work. He has touched the lives of many students during his teaching career leaving them instilled with values that recognize the importance of soil resources to society. His research on soil as a resource has had important implications for California agriculture and for the management of its natural resources.

American Society of Agronomy
California Chapter

2011 Scholarship Recipients & Essays

Essay Question:

Food comes from the grocery store, doesn't it? What are the challenges and opportunities for informing an increasingly urban population about production agriculture in California?

Scholarship Committee:

Brad Hanson, Chair
Rodrigo Krugner
Sharon Benes
Carol Frate

2011 Scholarship Award Winners

Sonia Rios, California State Polytechnic University Pomona

Born and raised in the Great San Joaquin Valley, I knew at a very young age that Agriculture is the foundation for our survival and the most important economic industry in California. Agriculture contributes more than 36.6 billion dollars in revenue in our state alone. With very few California residents aware of the significance of this agricultural foundation, many of those persons are located in urban areas. There are many barriers that contribute to this lack of knowledge to urban populations such as lack of free public resources, programs that educate about agriculture, cuts to youth agriculture programs such as Future Farmers of America (FFA), 4-H, and Junior Farmers. Even college agriculture programs are being challenged more than ever during these times.

There is lack of free resources and programs that can enhance the awareness of agriculture to the public. An exceptional example is The Dairy Council of California (http://www.dairycouncilofca.org). Agricultural Specialists travel to urban-area schools in a mobile transport (built to accommodate a live cow) to educate and demonstrate how milk and dairy foods are produced. The organization also provides a user-friendly website that provides instructions and educational materials to districts and teachers. If there are more programs that build awareness, we can teach children at a younger age about agriculture and make them aware that an important food like milk doesn't "come from the store".

Rapid changes in agriculture innovation and technology are another challenge to the upcoming young professionals in the agriculture industry, Ag Programs are usually independent and self-supporting, they usually do not have the land, up to date equipment, and funds necessary for fundamental hands-on learning experiences for state FFA, 4-H, and junior farmer programs. I feel local community awareness and education will boost the support needed for these types of programs to become more self sustaining, especially in urban located areas.

There are few agriculture-based universities remaining in the state due to budget cuts and in general people not knowing agriculture exist; I feel there is a need for more advocacy and support to prevent programs and professors from being downsized. In my own experience, it is obvious and unsettling to see these changes occurring in front of my eyes. My classmates and I are weary when we hear administrators speak about what the agriculture field will become in the future. For example, the last Agriculture University in southern California, Cal Poly Pomona's original major Plant Science. is on the verge of extinction. This program is especially special due to the curriculum is based on urban agriculture. If this is the case, maybe, faculty and staff at agriculture colleges/agencies need to acquire grant writing skills in order to be funded by local or state companies and corporations. Students also need to be taught how to organize rallies and need to know the importance on politics and policies, to know how the state government works, because we all know a majority of these issues are political. The situation has become more solemn, to say the least, in recent years due to the current economic crises, climate change, and population increase in urban areas. In this day in time agriculture educators, teachers, and the public have to start teaching agriculture awareness to younger ages, assist self-supporting organizations, and try to gain back control in our higher education institution. I am aware that my generation has an important part in keeping California agriculture healthy and selfsustaining, that is why I know I am doing my part of the treatment, by sharing my knowledge of California agriculture to those who come from urban areas that did not have the same privileges and experiences as I.

Megan Reese - University of California Davis

In an increasingly service-and information-based economy, the health of our American agriculture industry is crucial. California has been at the forefront of innovative and sustainable production practices. Informing the non-agricultural community of the social, technological, and essential nature of California farming will help our industry while creating an educated general public.

However, fewer and fewer citizens appreciate and understand agriculture. Urban lifestyles are now the rule. A mere two percent of our population is responsible for producing our food supply~ many people never have to interact with -or even think about -issues such as the source of their food. In a world of instant gratification, it is difficult to persuade people to think beyond what is in front of them in the aisles of the grocery store. The complex and amazing process that brings food to our table is often taken for granted. I see this ignorance in many of my friends, as their attitudes reflect the mindset of, "Food comes from the grocery store."

Despite these challenges, however, there are many opportunities to create an informed and agriculturally-conscious public. Perhaps some of the most effective programs are those aimed at educating youth with the intention of creating a heightened awareness in future generations. Agriculture in the Classroom is one such program, and pre-and post-test evaluations have confirmed an increased agricultural literacy. Other organizations, such as 4-H and FFA, instill a respect of rural lifestyles and agricultural business. A large scale media campaign promoting the catchphrase "Sustainable Production Agriculture" has the possibility of encouraging economic and useful farming practices while being informative and palatable to the consumer. Such an approach echoes the popular and effective "Got Milk," "Real California Cheese," and the California Almond Board's "A Can a Day" infomercials. In addition, those who value and are involved in agriculture should make a conscious effort to promote agriculture's merits, informing their peers, social organizations, and larger communities. Combining this grassroots campaign with the aforementioned media attention and youth focus groups can greatly enhance the public's agricultural literacy and appreciation.

Teresa Scrivano – California Polytechnic State University San Luis Obispo

Chocolate milk comes from a brown cow. One of many misconceptions about farming, this statement opens up a bigger problem than original location of agricultural products agricultural literacy has become a forefront issue leading to decreases in youth wanting to pursue agricultural careers all the way to misunderstandings in what happens when water is restricted from farm use.

The greatest awareness obstacle is psychological. Farming has not been given a good impression by the media and since urban populations have little interaction with their rural counterparts, they believe and make inferences from what they learn. In an urban setting, most children first learn about agriculture from television or by seeing the grocery store and associating it with food. In addition to this, once a person forms a view, it is often difficult to change it; any new argument will be used to supplement their old views. With the state's growing urban population and shrinking amount of farm land, agricultural awareness will only decrease if it continues on this path.

Nevertheless there are ways to overcome these obstacles. In this generation there has been an increasing reliance on computers and the internet which means this would be a great route to explore for advertising the bounty of California's agricultural wealth. One way to use the internet would be to come up with internet food coupons that require the consumer to learn a California agriculture fact in order to get the coupon. This would both educate them and give them monetary incentive to learn more. In recent years farmers' markets have also become increasingly popular-partly due to the "Know Your Farmer, Know Your Food" campaign by the USDA-and these consumer-farmer interactions are helping to bring back the knowledge of where and how the food came there. These relationships could be built on to encourage citizens to become more aware of the diversity and abundance of agricultural products California hosts.

American Society of Agronomy
California Chapter

General Session

Agricultural Certification Programs-Opportunities and Challenges

Session Chair:
Larry Schwankl

Food Marketing and Distribution Trends: Buyers require more Services from Suppliers

Roberta Cook, Extension Specialist
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American Society of Agronomy
California Chapter

Session I
Nutrient Management

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Understanding and Correcting Nutrients in Nut Crops

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Introduction

Deciduous trees require 14 elements for normal growth and reproduction. These essential elements are classified as either macronutrients (N, P, K, Ca, Mg, S) or micronutrients (Fe, Mn, Cl, B, Cu, Zn, Ni, Mo) based on the concentration at which they normally exist in plants. Each is essential for particular functions in the plant. Macronutrients are the basis for organic compounds, such as proteins and nucleic acids. They also serve in the regulation of pH and water status of plant cells. Micronutrients serve as the constituents of enzymes (compounds which provide a new chemical reaction pathway with a lower activation energy), plant growth regulators such as auxin, cell membranes, and the photosynthetic pathway. Sodium (Na), although present in plant tissue, is not an essential element for deciduous tree crops. Plant nutrients are also important in disease resistance and fruit quality, and the balance between the various elements can affect plant health and productivity. Certain elements (Cl, B, and Na) commonly reach toxic concentrations in plant tissue when excessive levels exist in the soil or irrigation water. This imbalance can lead to other deficiencies, and severely impact the productive ability of the plant. Optimization of nut crop productivity and orchard quality requires an understanding of the nutrient requirements of the tree, the factors that influence nutrient availability and demand, and the methods used to diagnose and correct deficiencies. This paper will discuss important principles of plant nutrition that are the basis for developing a sound nutrition management program.

Factors Affecting the Nutrient Supply to the Plant

Although nutrients are taken up into the tree along with water, the absorption of water and nutrients involve different physiological processes. Water uptake depends on physical forces in the soil and within the plant, which are passive and dependent upon a concentration gradient. In contrast, nutrient absorption is selective, requires expenditure of respiratory energy, and involves specialized cells and tissues located at the tips of roots. The efficiency and rate of nutrient absorption are greatest in the root tip region, but there is increasing evidence that other portions of the root are also capable of nutrient uptake. The fine, brown roots are also thought to contribute substantially to nutrient uptake because of their length and surface area.

Soil factors such as soil type and texture, soil moisture, pH and soil depth, as well as plant factors including root distribution and density, rootstock, fruit load and shoot growth, all influence deciduous tree nutrition. Soil pH is a measure of the hydrogen ions present in the soil nutrient medium readily available for plant uptake. Its log scale ranges from 1 to 14, with 1 being highly acidic and 14 highly basic, or alkaline. A pH of 7 represents equal amounts of acid and base and is therefore neutral. Soil pH has a significant effect on nutrient availability. High pH (>7.5) greatly limits the solubility of many elements (i.e. Zn, Cu, Mn, Fe), while low soil pH can lead to deficiencies of P or Ca and toxicities of Al, Fe or Mn. Similarly, low soil temperature, poor aeration, or the presence of a hardpan can limit the plant's ability to obtain nutrients by limiting root growth and health.

Since all nutrients are supplied as dissolved ions in the water flow to roots, poor irrigation practices resulting in low soil water content reduce the availability of nutrients for plant uptake. Dry soil conditions also limit the concentration of nutrients (such as potassium) in soil water readily available for plant uptake. Under these circumstances, addition of more nutrients may not alleviate the deficiency; the solution lies instead in correction of the soil conditions that limit nutrient availability.

Amendments intended to change pH or improve soil structure can influence nutrient availability to the plant. However, it is essential that all aspects of the orchard and the production system be considered before deciding on such a course of action.

Environmental factors such as temperature, disease, salinity and the presence of high levels of specific elements may also influence plant nutrition. Each factor affects plant nutrition by influencing either the availability of nutrients to the root or the effectiveness of root uptake of the elements. Disease and salinity affect nutrient uptake by limiting root growth, and hence, root volume. Excessive salts within the root zone also decrease the percentage of available water taken up by the tree before the energy gradient induces plant stress and limits productivity.

DIAGNOSING ORCHARD NUTRIENT STATUS

Soil analysis

Soil analysis provides information on nutrient content and the soil chemistry affecting its availability. Cation exchange capacity (CEC, the ability of a soil to retain cations for subsequent release into the soil solution), pH, and salinity all affect the availability of nutrients present in the soil. It is **CRITICAL** that adequate soil analyses be performed **PRIOR** to orchard establishment for accurate assessment of the site for nut crops. **These samples are directly, and almost exclusively, focused on the salinity characteristics of the soil**. **High salinity must be corrected prior to planting to avoid poor orchard performance and tree loss**. Other soil chemical conditions, such as high pH combined with high soil lime (calcium carbonate) limit zinc, iron, manganese, and copper availability. The saturation percentage (SP) can also be used as a general guide to soil texture and water holding capacity. Pre-plant soil assessment often reveals chemical or physical conditions unsuitable for tree crops and thus saves the investor from serious financial loss.

Established orchards benefit from soil analysis by assessing the impact of fertilization and irrigation management. Monitoring trends in soil nitrate-nitrogen concentration within the root zone are especially important to avoid groundwater contamination and excessive fertilizer expenditures. It is also essential for a proper investigation into the cause for isolated poor tree performance. Soil analysis is most valuable when combined with a visual symptom assessment of the tree and tissue analysis. **Trees are complex, long-lived perennial plants whose nutritional status represents an integration of age and cultural practices in addition to soil nutrient availability!** Of greatest concern is the nutritional status of the tree– and not the soil. Hence, soil analysis is usually recommended after a nutrient deficiency is suspected from the presence of foliar symptoms and tissue testing.

Collecting soil samples representative of the entire orchard is challenging and expensive. Deciduous tree roots engage a large volume of soil, and soil type often varies within the orchard. Soil chemistry also differs with depth from the surface. Surface soil chemistry and its nutritional status can be quite different from soil only one foot below it. Therefore, soil samples should be taken from the profile where roots are most active (typically the upper four feet of the profile). For a thorough analysis, soil samples should be taken in single-foot increments from five to ten different locations within the area of the orchard in question. The multiple samples taken from the same depth are then composited for submission to the laboratory. This process should then be repeated in other areas of the orchard, and compared to samples taken from the area of highest productivity. The number of areas sampled depends upon the different soil types occurring within the orchard. Nutrient deficiencies can be associated with soil differences (such as old creek beds), differences in topography, sand deposits, cuts or fills, or old coral and pasture sites.

When soil sampling, also consider the effect that irrigation method has on root distribution and soil fertility within the root zone. Flood or basin irrigation applies water over a large area relatively uniformly and results in wider distribution of roots and area for nutrient uptake. Hence, sampling near the edge of the tree canopy but to one side of where fertilizer applications are made provides a reasonable assessment of soil nutrient status. With mini-sprinkler systems, sampling should be performed within the wetted pattern, but avoiding its edge where salts may accumulate. Orchards under drip irrigation require sampling approximately half-way between the emitter source and the edge of the wetted area. Due to the large difference in soil water content with distance from the emitter source, sampling too close to the emitter can lead to erroneously low soil nutrient assessment of some elements, particularly nitrogen because it exists as a leachable form in soil solution.

Interpretive Guides for Soils

The value of soil analysis as a guide to fertilization practices is limited by the inability to predict the relationship between soil chemical analysis and plant nutrient uptake. **Soil analysis is best suited for assessment of pH, saturation percentage, CEC, and salinity**. Diagnosis of observed nutrient deficiencies can be aided by knowing the soil pH, because it affects the availability (not the quantity!) of mineral nutrients. Nutrients may be abundant in the soil, but in order for them to be available for plant uptake, they must be in "the soil solution". Soil solution is defined as the elements present in the water readily available for plant use. A low pH (<5.5) may result in deficiencies of Ca, Mg, P or Mo and perhaps excesses of Mn, Fe or Al. High pH (>7.5) may immobilize Mn, Zn, Fe or Cu, making them unavailable to the plant. High levels of calcium carbonate (lime) in the soil can induce deficiencies of Fe, Mn or Zn and may also make pH adjustment of the soil difficult. The presence of any soil physical characteristic that limits root growth or water penetration is also likely to affect nutrient uptake.

Recent research on the effects of salinity in pistachio indicates it has significantly greater salt tolerance than other nut crops. No yield reduction was recorded using irrigation water with an EC_w (Electrical Conductivity) of 8.0 dS/m and soil with an EC_e (electrical conductivity of the saturation extract) of 9.4 dS/m (at 25^0 C). Soil chloride (Cl) and sodium (Na) in excess of 50 meq/liter were tolerated without negative effects. Experience in saline areas on the Westside of the San Joaquin Valley suggests pistachios tolerate 20-30 meq/l of Na and Cl and up to 4 ppm Boron (B) in the soil without adverse impacts on yield. Pistachios may be tolerant of exchangeable sodium percentages (ESP) as high as 15%. However, high exchangeable sodium levels in the surface soil can cause structural deterioration (soil particles repel one another and reduce the air space for water movement) and subsequent water infiltration problems. Hence, water stress can be an indirect but significant effect of high soil sodium levels in the surface soil.

The soil conditions under which pistachios can be successfully grown are **NOT** those suitable for walnuts, almonds or pecans! Walnuts thrive on the best alluvial soils existent in the San Joaquin Valley. Ideal walnut soils have total salt levels (ECe) of 1.5 dS/m or less, a sodium absorption ratio (SAR) less than 5.0, chloride concentration less than 5.0 meq/L and boron levels of 0.5 ppm or less. Depending upon the rootstock selected, almonds can tolerate slightly higher salinity levels, but they should not be considered salt tolerant. Growing almonds in soils higher than optimal salinity presents significant problems associated with specific salt toxicity to plant tissues which limit productivity and longevity. Almonds grown on soils with elevated sodium or total salinity also experience major problems with soil water infiltration, resulting in sustained plant stress and reduced productivity, especially during the extended harvest period. Prolonged soil surface wetness associated with low infiltration also greatly increases the risk of crown and root rot diseases. Remember; roots need oxygen as badly as humans do!

Plant analysis

Leaf analysis is more useful in diagnosing mineral deficiencies and toxicities in tree crops than soil analysis. The mineral composition of a leaf is dependent on many factors, such as its stage of development, climatic conditions, availability of mineral elements in the soil, root distribution and activity, irrigation, etc. **Leaf samples integrate all these factors, and provide an estimate of which elements are being adequately absorbed by the roots**. The main limitation with leaf analysis is that it does not tell us **why** the nutrient is deficient. Leaf tissue can also vary significantly in nutrient content within individual trees, as well as between locations within a single orchard. **To maximize the value of leaf analyses, one must therefore adhere to strict standardization of the sample procedure and locations sampled**.

Sampling procedure

Concentrations of leaf nutrients vary with time, leaf age, position in canopy and the presence or absence of fruit. Trees within an orchard may also vary in their nutrient status as a result of differences in soil fertility, water availability or light exposure. Therefore, it is essential that sampling techniques be standardized if valid comparisons are to be made. **Choice of sampling method also varies depending on the purpose of the survey**. If the aim is only to identify the problem in an isolated tree or area, then sampling just a few poor and some good trees should suffice. If a determination of overall nutrient status in a large orchard is required, then more extensive sampling of trees from many sites will be required.

The correct leaf sampling procedure differs slightly by nut commodity. For pistachios, fully expanded sub-terminal leaflets (pistachios typically have five leaflets per compound leaf) are randomly collected from **non-fruiting branches** at about six feet from the ground. Four to ten leaves are typically collected per tree, and 10-20 trees are sampled in each orchard block. **Leaves sprayed with micronutrients typically cannot be analyzed for that nutrient since the surface contamination cannot be removed.** Hence, no leaves having received in-season nutrient sprays for the elements of interest should be sampled. This means sampling before a nutrient treatment, or sufficiently long after treatment to allow for new growth. Orchards with specific micronutrient problems may even justify the labor required to temporarily bag shoots prior to a nutrient spray for sampling at a later date. The challenges associated with acquiring an accurate tissue sample re-enforce the value of visual nutrient symptom assessment, especially in the case of zinc, copper, boron, and nitrogen. Samples should be kept in labeled **paper** bags and submitted to the analytical service within 24 hours of collection. Leaves are living organs! Process them promptly! Pistachios are sampled from late July through August. The pistachio critical levels established through experimentation and observations (Table 1) are based on this timing. However the comparison of good trees against poor ones can be done at any time. Samples collected at times other than from late July through August may have nutrient concentrations different than those recommended in the critical values table and must be interpreted with care.

For **walnuts,** the least change in leaf nutrient concentration occurs between late June and early July. The sample date is different from pistachio due to the large boron requirement of pistachio, which continues to rise in the leaf tissue until nut maturity. Walnut nutrient studies performed over decades by UC researchers have examined leaves, petioles, hulls, nuts, stems, and even bark as the basis for critical level establishment. It was determined that fully expanded leaves from spurs were the most reliable. **No designation is presently made between selection of fruiting over non-fruiting walnut spurs**. Select spurs from as high as possible, but at least six feet off the orchard floor. Each sample should consist of about 50 leaflets (a walnut leaf contains three to five leaflets on a single petiole or stem). Critical and adequate tissue levels for July can be found in Table 2.

UC guidelines recommend tissue **sampling almonds** from July through mid-August. The critical values reported in Table 3 are based on **nonfruiting spurs sampled in July**. Collect approximately 100 spur leaves at least six feet off the ground. Leaves within the sample must be from the same cultivar, on the same rootstock, and from trees of similar growth status. Sample different cultivars and trees of questionable condition separately to better assess orchard nutrient status. Label the samples so you can refer to their location later. Do not delay in delivery to the laboratory.

Pecans have multiple leaflets within a single leaf, and there are several leaves alternately opposed along a current season's shoot. **Sample two leaflets opposite one another mid-way on the leaf, and select a compound leaf that is mid-way along the shoot**. All four sides of the tree should be sampled, and a sample should represent about 60 leaves. July is the best time to sample in California. Table 4 provides the suggested nutrient levels typically used by California. Additional information is available at: http://cals.arizona.edu/pubs/diseases/az1410.pdf.

Table 1. Pistachio Critical and Suggested Levels for August Leaf Samples

Element	Critical Value	Suggested Range	Reference
Nitrogen (N)	1.8%	2.2 -2.5%	Weinbaum, et.al. 1988, 1995
Phosphorus (P)	0.14%	0.14-0.17%	
Potassium (K)	1.6%	1.8 - 2.0 %	Brown, et.al. 1999
Calcium (Ca)	1.3% (?)	1.3-4.0%	
Magnesium (Mg)	0.6% (?)	0.6-1.2%	
Sodium (Na)	(?)	(?)	
Chlorine (Cl)	(?)	0.1-0.3%	
Manganese (Mn)	30 ppm	30-80 ppm	
Boron (B)	90 ppm	150-250 ppm	Uriu,1984; Brown, et.al.,1993
Zinc (Zn)	7 ppm	10-15 ppm	Uriu and Pearson.1981, 1983,1984,1986
Copper (Cu)	4 ppm	6-10 ppm	Uriu, et.al. 1989

ppm = parts per million or milligrams/kilogram dry weight. *% = parts per hundred or grams/kilogram dry weight*

Table 2. Walnut Critical and Suggested Levels for July Leaf Samples

Element	Critical Value	Suggested Range
Nitrogen (N)	2.1%	2.2 -3.2%
Phosphorus (P)	0.10%	0.14-0.3 %
Potassium (K)	1.0%	1.2 -1.7 %
Calcium (Ca)	0.9% (?)	>1.0%
Magnesium (Mg)	(?)	> 0.3%
Sodium (Na)	(?)	< 0.1%
Chlorine (Cl)	(?)	0.1-0.3%
Manganese (Mn)	(?)	> 20 ppm
Boron (B)	20 ppm	40-300 ppm
Zinc (Zn)	<18ppm	20-30 ppm
Copper (Cu)	4 ppm	6-10 ppm

Table 3. Almond Critical and Suggested Levels for August Leaf Samples

Element	Critical Value	Suggested Range
Nitrogen (N)	2.0%	2.2 -2.5%
Phosphorus (P)	< 0.1%	0.1-0.3%
Potassium (K)	1.0%	1.4–1.8 %
Calcium (Ca)	(?)	> 2.0%
Magnesium (Mg)	(?)	> 0.25%
Sodium (Na)	(?)	< 0.25%
Chlorine (Cl)	(?)	< 0.3%
Manganese (Mn)	(?)	> 20 ppm
Boron (B)	30 ppm	30-65 ppm
Zinc (Zn)	15 ppm	18-30 ppm
Copper (Cu)	4 ppm	6-10 ppm

Table 4. Suggested Levels for Pecan Leaf Tissue Sampled in July

Element	Suggested Range
Nitrogen (N)	2.7 -3.0%
Phosphorus (P)	0.18-0.30%
Potassium (K)	1.25 – 1.5 %
Calcium (Ca)	1.0-2.5%
Magnesium (Mg)	> 0.30%
Sodium (Na)	< 0.10%
Chlorine (Cl)	< 0.3%
Manganese (Mn)	80-300 ppm
Boron (B)	30-80 ppm
Zinc (Zn)	50-200 ppm
Copper (Cu)	> 4 ppm

Interpreting leaf analyses

Results of tissue analysis are reported as the concentration of a nutrient on a dry weight basis. For **macronutrients**, concentrations are reported on a percent basis (grams of nutrient per 100 g dry weight), while **micronutrients** are reported in parts per million (microgram nutrient per gram dry weight). For each element, the laboratory will usually identify the 'Critical Value' (CV), or the 'Adequate Range' to aid in interpretation of the results. 'Critical Value' or 'Critical Level' refers to the nutrient concentration at which plant yield is estimated to be at 95% of maximum, or at which distinct symptoms of deficiency are present. Tissue nutrient concentrations below this level will result in poor plant growth and reduced yields. The 'Adequate Range' refers to the nutrient concentration range at which growth is optimal. Above this nutrient concentration, plant growth may be inhibited by certain nutrients such as Boron and Chloride, which burn plant tissue at high levels. There is no correlation between macronutrient concentrations above the adequate level and increased plant performance. In fact, several studies have shown predisposition to diseases and poor fruit quality with abnormally high nitrogen levels. Excessive nitrogen in the plant tissue is also indicative of soil applications which exceed demand and plant uptake capacity. The excess and highly mobile nitrogen can then be easily leached beyond the root zone and into precious groundwater. Excessive potassium fertilization is quickly bound to soil particles electrostatically, so leaching is not a concern. Over application of potassium is also less likely due to its high cost. Critical values are crop specific. It is essential that the nutrient recommendations supplied by the testing laboratory reflect comparison to the adequate and critical values for the nut crop in question, since nutrient requirements differ significantly between crops. This is especially true for pistachio, since it has a much higher boron and potassium requirement than other deciduous tree crops and also tolerates more salinity.

Although valuable as a tool to assess orchard nutritional status, critical values are **not** absolute. They are often based on detailed visual assessment of general tree health and not necessarily on yield or crop quality research. Some nutrients, such as boron and zinc during bloom and potassium and nitrogen during pistachio kernel filling, may also require temporary supplementation to optimize production (Brown, 1993, 1999; Weinbaum, 1995). Ideally, scientific fertilization practices would replace that amount consumed by the plant in growth and crop production. To achieve this objective, the total annual requirement of each nutrient would have to be determined, as well as the percentage removed from the orchard system as crop. Critical values for nitrogen, potassium, boron, zinc, and copper have been established for most nut crops from research projects conducted over the decades. Others are estimates from field observation and levels deemed acceptable in other deciduous crops. Armed with knowledge of visual symptoms, soil and tissue sampling procedures, and results from studies assessing specific annual nutrient consumption, growers and crop consultants should be capable of developing effective nutrient management programs which result in highly productive and healthy orchards

Literature Cited

Beede, R.H., Padilla, J., and D. Thomas. 1991. Foliar boron and zinc nutrition studies in pistachio. 1991. In: Calif. Pistachio Ind. Ann. Rpt. 1991. pp. 121-126.

Brown, P., Ferguson, L. and Geno Picchioni. 1993. Boron nutrition of pistachio: Final report. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 57-59.

Brown, P., Zhang, Q., and Bob Beede. 1993. Effect of foliar fertilization on zinc nutritional status of pistachio trees. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 77-80.

Brown, P., Zhang, Q., and Bob Beede. 1996. Foliar spray applications at spring flush enhance zinc status of pistachio trees. In: Calif. Pistachio Ind. Ann. Rpt. 1996. pp. 101-106.

Brown, P., Zhang, Q., Huang, Z. Holtz, B., and Craig Hornung. 1999. Agronomic and economic responses of mature 'Kerman' pistachio trees to potassium applications in California. In: Calif. Pistachio Ind. Ann. Rpt. 1999. pp. 84-85.

Reisenauer, H.M., Quick, J., Voss, R.E., and A. L. Brown. 1983. Chemical Soil Tests for Soil Fertility Evaluation. In: Soil and Plant Tissue Testing in California. University of California Press. Bull. 1879. pp. 39-41.

Uriu, K., and J. Pearson. 1981. Diagnosis and correction of nutritional problems. In: Calif. Pistachio Ind. Ann. Rpt. 1981. pp. 30.

Uriu, K., and J. Pearson. 1983. Diagnosis and correction of nutritional problems, including the crinkle leaf disorder. In: Calif. Pistachio Ind. Ann. Rpt. 1983. pp. 79.

Uriu, K., and J. Pearson. 1984. Diagnosis and correction of nutritional problems, including the crinkle leaf disorder. In: Calif. Pistachio Ind. Ann. Rpt. 1984. pp. 49-50.

Uriu, K., and J. Pearson. 1986. Zinc deficiency in pistachio-diagnosis and correction. In: Calif. Pistachio Ind. Ann. Rpt. 1986. pp. 71-72.

Uriu, K., Teranishi, R., Beede, R., and J. Pearson. 1989. Copper deficiency in pistachio. In: Calif. Pistachio Ind. Ann. Rpt. 1989. pp. 77.

Weinbaum, S.A., and T.T. Muraoka. 1988. Nitrogen usage and fertilizer recovery by mature pistachio trees. . In: Calif. Pistachio Ind. Ann. Rpt. 1988. pp. 84-86.

Weinbaum, S.A., Picchioni, G. A., Brown, P.A., Muraoka, T.T., and L. Ferguson. 1991. Nutrient demand, storage and uptake capacity of alternate bearing pistachio. In: Calif. Pistachio Ind. Ann. Rpt. 1991. pp. 148-157.

Weinbaum, S., Brown, P., and R. Rosecrance. 1993. Assessment of nitrogen uptake capacity during the alternate bearing cycle. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 47-48.

Weinbaum, S., Brown, P., and R. Rosecrance. 1995. Assessment of nitrogen and potassium uptake capacity during the alternate bearing cycle. In: Calif. Pistachio Ind. Ann. Rpt. 1995. pp. 56-60.

Foliar Fertilization of Stone Fruit – Boron, Calcium and Zinc

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Introduction

Applying nutrients as foliar sprays can be an effective way of supplying those nutrients to plants. However, many times no benefit is seen from such applications. How can a stone fruit grower be assured a foliar spray will be beneficial? The first basic principle to follow can be simply stated as follows: if a given nutrient is not limiting in the plant, adding more will provide no benefit. This is a logical statement but it isn't always easy to put into practice. How does one know if a nutrient is limiting? Following plant physiology principles and sampling procedures can greatly increase the chances of getting the right answer. Thus, this paper will emphasize the physiological and sampling principles that will help determine the need for applying boron, calcium or zinc to stone fruit, and also the best methodology to follow.

Boron – the situation of a mobile nutrient (at least in stone fruit)

Boron (B) is considered to be immobile in most plants. However, work by Patrick Brown and his coworkers (Brown and Hu, 1996; Brown and Shelp, 1997) has demonstrated that boron is quite mobile in stone fruit and many other fruit crops. This is due to the transport sugar, sorbitol, which is abundant in stone fruit, but not in most other plants. Boron forms a complex with sorbitol and is thus easily transported throughout the plant. The significance of this is that a mobile nutrient is more straightforward to sample for and is easier to correct when deficient.

The standard leaf sampling procedure in mid summer can be useful for mobile nutrients like boron. Generally, researchers have established the threshold for B deficiency to be about 15 to 20 ppm in mature, mid-shoot leaves. Research we have done with mature trees in sand tanks has suggested even 25 ppm B may be limiting to some plant processes in peach. Therefore, we recommend keeping the leaf B level above 25 ppm to ensure optimum productivity. However, it is important to keep in mind that B toxicity can be a problem with stone fruit. Peach has been reported to be particularly sensitive to this disorder (Cibes et al., 1955; Dye et al., 1984). Toxicity has been reported at leaf levels of about 100 ppm B.

Boron plays a major role in fruit set in orchards. In nut crops where greater set means greater yields, B sprays have sometimes increased yields (Nyomora et al., 1997). However, heavy set is often not desirable in peach orchards as it just means an increased thinning bill. In 2005 (Johnson, 2005), we surveyed many orchards in sandy locations where B deficiency might occur (many being near sites where B deficiency had been identified in grape vineyards (Christensen et al, 1978)). Only 2 orchards tested below 25 ppm B in mid-season mature leaves. Subsequent foliar boron applications did not improve fruit set, productivity or fruit size in these orchards. We have concluded that B deficiency is a rare occurrence in stone fruit orchards in the

San Joaquin Valley. If B deficiency is suspected, it would certainly be important to take a leaf sample first to make sure B levels are sufficiently low to warrant an application.

Calcium – the situation of an immobile nutrient

Calcium (Ca) is probably the most immobile nutrient in plants. This leads to different physiological conditions within the plant and a completely different strategy for sampling and correcting potential deficiency compared to the mobile nutrient boron. First, the standard mid-summer leaf sampling protocol does not give a good indication of fruit Ca. The amount of Ca in leaves is far greater than in the fruit and seasonal patterns are completely opposite. In the leaves, calcium accumulates throughout the season, reaching levels as high as 3 to 4%. On the other hand, fruit Ca drops throughout the season and by harvest can be as low as 250 ppm (more than100x less than in the leaves). Since Ca is an important component of cell walls, and since many fruit disorders have been associated with low Ca (bitter pit of apples, blossom end rot of tomatoes, etc.), it is natural to assume that these low Ca levels in fruit could lead to problems with fruit quality. However, we need to return to the original principle presented at the beginning of this paper and ask if calcium, even at 250 ppm, is truly limiting to any processes within the fruit. Several areas of research suggest that it is not. First, certain rootstocks have been shown to significantly increase calcium in the fruit. However, this provided no benefit in terms of firmer fruit, greater disease resistance or other improvements in fruit quality (Ferrari, 2004). Second, multiple foliar applications of various Ca containing materials, did nothing to improve fruit quality or storage life (Johnson et al., 1998; Crisosto et al., 2000).

Our conclusions about calcium in stone fruit are as follows: first, sampling for Ca in mid summer leaves is of limited usefulness. It may identify Ca deficiency in the tree as a whole (seldom seen in the field), but does not identify potential fruit deficiency. Second, even though Ca is very low in fruit, we see little evidence that it is truly deficient or limiting to any plant processes. Thus, increasing fruit Ca by root uptake or multiple foliar applications provides no benefit.

Zinc – more mobile than calcium but less than boron

In many fruit trees zinc (Zn) does not appear to be very mobile. At least foliar sprays do not readily supply Zn to the roots (Swietlik, 2002). However, our research has shown foliar applied Zn does move into the root system in a peach tree (Sanchez et al., 2006). Perhaps, this might be a situation similar to boron where zinc in mobile in one plant but not in another. More research is needed to determine the exact nature of zinc movement in fruit trees.

Since Zn is somewhat mobile in a peach tree, mid-summer leaf sampling can be useful for determining deficiency. However, it isn't as sensitive as some other methods. It seems that Zn is slowly exported out of mature leaves during the late spring and early summer, so the level can be quite low even in trees well-supplied with zinc (Johnson et al., 2008). We have found zinc levels in mid-summer, mature leaves to be similar between deficient and sufficient trees. Thus, a mid summer leaf sample should be interpreted carefully. Certainly a value of 10-12 ppm Zn indicates deficiency, but values around 15 ppm are common in healthy orchards with no Zn deficiency, even though the published deficiency threshold is 15 ppm. It might be helpful to sample during other times that appear to be more indicative of the actual Zn status of the tree. We have found dormant sampling of fruiting shoots in the lower canopy to be a useful approach (Johnson et al., 2006). Many orchards show Zn levels of 30 to 50 ppm, which is an indication of adequate Zn and requires no corrective measures. Only those orchards testing around 20 ppm and below would need treatment.

The preferred method of correcting Zn deficiency in stone fruit orchards is by foliar applications. Even though the uptake is often only 2 to 3% of that applied, it is generally more efficient than soil applications. There are dozens of commercial formulations available for growers to use, so the question often arises as to which material is the most efficient. We have conducted a series of experiments to answer this question. Using peach seedlings in the greenhouse, we found some formulations were more effective than others at correcting Zn deficiency symptoms (Johnson et al., 2010). After several experiments where we compared about a dozen materials, we concluded that zinc sulfate (36% Zn) is the most cost effective material. In some tests, zinc nitrate performed slightly better than zinc sulfate, but it costs considerably more. Thus, zinc sulfate is still the most cost effective material to use in most situations.

We also conducted several experiments to determine the best timing for applying zinc sulfate. We purposely avoided the spring period because of the danger of phytotoxicity on fruit (zinc nitrate is even more phytotoxic). Instead, we focused on the fall and dormant periods. Our results indicated that early fall was more effective than late fall and both were better than the dormant period (Johnson et al., 2007). The principle here is that the leaves provide a much larger target than dormant wood for interception of the spray and that active leaves have more capacity for zinc uptake than senescing leaves.

In conclusion, mid summer leaf sampling to determine the presence of Zn deficiency should be used with caution since leaf Zn levels can be low even in trees well supplied with zinc. A better indication of the true Zn status of the tree might be obtained by using a dormant shoot sampling procedure. To correct a deficiency, the most efficient and cost effective method is to apply zinc sulfate (36% Zn) in early to mid fall.

Literature Cited

Brown, P. H. and H. Hu. 1996. Phloem mobility of boron is species dependent: evidence for phloem mobility in sorbitol-rich species. Annals of Botany 77:497-505.

Brown, P. H. and B. J. Shelp. 1997. Boron mobility in plants. Plant and Soil 193:85-101.

Christensen, L. P., A. N. Kasimatis, and F. L. Jensen. 1978. Grapevine Nutrition and Fertilization in the San Joaquin Valley. University of California Division of Agriculture and Natural Resources Publication 4087.

Cibes, H. R., E. Hernandez, and N. F. Childers. 1955. Boron toxicity induced in a New Jersey peach orchard. Part I. Proceedings of the American Society for Horticultural Science 66:13-20.

Crisosto, C. H., K. R. Day, R. S. Johnson, and D. Garner. 2000. Influence of in-season foliar calcium sprays on fruit quality and surface discoloration incidence of peaches and nectarines. Journal of American Pomological Society 54(3):118-122.

Dye, M. H., L. Buchanan, F. D. Dorofaeff, and F. G. Beecroft. 1984. Boron toxicity in peach and nectarine trees in Otago. New Zealand Journal of Experimental Agriculture 12:303-313.

Ferrari, G. M. 2004. The effect of interspecific peach hybrid rootstocks [K119-50 (*Prunus salicina* x *P. dulcis*) & P30-135 (*P. persica* x *P. salicina*)] on peach (*P. persica* L. Batsch cv 'Flavor crest' and 'Loadel' scion nutrient concentrations and fruit quality. Masters Thesis, University of California, Davis. 77 p.

Johnson, R. S. 2005. Investigating the role of boron in stone fruit orchard productivity and fruit quality. California Tree Fruit Agreement. 2005 Annual Research Report, pp. 107-109.

Johnson, R.S., H. Andris, K. Day, and R. Beede. 2006. Using dormant shoots to determine the nutritional status of peach trees. Acta Horticulturae 721, pp. 285-290.

Johnson, R.S., R. H. Beede, K. Day, and P. Brown. 2010. Comparing the efficiency of different foliarly-applied zinc formulations on peach and pistachio trees by using ^{68}Zn isotope. California Department of Food and Agriculture Fertilizer Research & Education Program Conference 20th Anniversary Proceedings, pp. 97-100.

Johnson, R. S., C. H. Crisosto, R. Beede, H. Andris, and K. Day. 1998. Foliar calcium sprays to improve peach fruit quality. California Tree Fruit Agreement. 1998 Annual Research Report, pp. 92-99.

Johnson, R. S., W. A. Johnson, R. C. Phene. 2008. Zinc movement and distribution within a peach tree. California Plant and Soil Conference Proceedings, pp. 23-27.

Johnson, R. S., S. A. Weinbaum, and R. H. Beede. 2007. Exploring agrotechnical and genetic approaches to increase the efficiency of zinc recovery in peach and pistachio orchards. Proceedings of the 15th Annual Fertilizer Research & Education Program Conference pp. 14-18.

Nyomora, A. M. S., P. H. Brown, and M. Freeman. 1997. Fall foliar-applied boron increases tissue boron concentration and nut set of almond. Journal of the American Society for Horticultural Science 122(3):405-410.

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. 2002. Zinc nutrition of fruit crops. Hort Technology 12(1):45-50.

Potassium Nutrition of Winegrapes

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Introduction

Potassium (K) is the most abundant inorganic element found in grapes, and it is the main cation in must and wine, with concentrations far exceeding those of calcium, magnesium, and sodium (Harbertson and Harwood, 2009). K deficiencies can lead to reduced vine growth, premature leaf drop, and yield loss (Christensen et al., 1978). In grapes, as in all higher plants, K plays a key role in enzyme activity and the uptake of other cations, anions, and sugars by cells; and it is involved in cell osmoregulation, thus controlling plant water relations, cell turgor, and growth.

Fertilizer K needs of grapevines depend on production goals (fruit yield and desired wine quality), the grape rootstock capacity to absorb and translocate K to the scion, and the soil capacity to supply K to plants and retain it against loss. Variations in these factors make it unlikely that a single prescription for K management would work well in all vineyards.

Excessive K levels in fruit

The need to understand and properly manage K is made doubly important by the fact that excess K concentration in fruit has a negative effect on wine quality. Excessive K decreases free acid levels and combines with tartaric acid to form insoluble potassium bitartrate during winemaking and storage. High K in the fruit can lead to an increase in pH in the juice, must, and wine, causing the wine to have a flat taste. High pH of juice and wine also decreases the color quality of red wines and increases its susceptibility to oxidative and biological spoilage (Mpelasoka et al., 2003). Recently, researchers have identified genes expressed in berry skins during the pre-veraison period of development that control accumulation of potassium in the fruit (Davies et al., 2006).

A 2006 survey of Lodi Winegrape district growers conducted by the authors in cooperation with the Lodi Winegrape Commission revealed that 85% of vineyards surveyed had received K fertilizer at least once in the preceding three years. Also, 28% of the vineyard blocks in the survey reportedly had some indication of K deficiency, such as low petiole K, low soil test K, or low yields that were corrected by K applications. Only a few survey respondents indicated any problem of excessive K levels in fruit; however, it seems likely that few growers would have the information needed to evaluate this for individual vineyard blocks.

K uptake by vines and fruit

K harvest removal by grapes – on the order of 5 lb/ton (5 kg/metric ton) of fruit – is small compared to removals by forages and many other crops. K uptake rate between veraison and harvest can be high. In some soils, the volume of soil explored by roots under drip irrigation may be quite small late in the season, resulting in a decreased uptake of K. This was observed by Klein et al. (2000) on drip irrigated winegrapes in Israel.

K concentration in berries can vary over a wide range. K uptake by berries increases rapidly during the ripening phase. Most of the fruit K is in the pulp, because pulp accounts for 90% of the fruit weight; but skins have a higher concentration of K and under some conditions will contribute K to wine (Harbertson and Harwood, 2009). Some studies show that a significant portion of the K accumulating in berries after veraison is translocated from other plant parts. Other studies do not show much remobilization of K late in the season. It is possible that lack of agreement among researchers is due to the large number of factors that influence uptake of K by berries, including soil properties, weather, rootstock characteristics, and irrigation practices. Heavy fruit loads can lead to K deficiencies; however a link between crop load and berry K concentration has not been established (Mpelasoka et al., 2003).

Rootstock influences on K uptake

Several researchers have demonstrated that rootstocks differ in the capacity to supply K to the scion vines. This may be due to differences among the rootstocks in root extent and geometry, root affinity for K, and capacity to translocate K to the scion.(Mpelasoka et al., 2003; Ruhl et al., 1988). Research on Syrah variety showed that root pressure but not transpiration or shoot/root dry weight accounts for rootstock differences in K accumulation (Kodur et al., 2010). University of California researchers have shown that vines on rootstocks with *Vitis berlandieri* genetic background, such as 420A, 110R, 5BB, 5C, and 1103P are sensitive to K deficiency. Freedom, 44-53, and 039-16 are examples of rootstocks that provide high K to the scion vines (Lambert et al., 2008; Wolpert et al., 2005).

Diagnosing K vine deficiencies and excesses

Petiole analysis has been the chief management tool for assessing the need for K applications to vines. Soil sampling, especially during preparation of land for planting, is also used. In the Lodi winegrape district, petiole sampling is used by many growers and crop consultants. Interpretive values for petiole K were published by U.C. in 1978 (Christensen et al., 1978). Limitations of petiole and blade analysis for assessing K fertilizer requirements are well known and stem from the following problems:

- Lack of calibration data for many of the common rootstock-scion combinations grown in California

- Variability in K content of samples taken from different positions on the vine – shaded vs. non-shaded, trimmed shoot vs. not trimmed, etc.
- Combining (compositing) of samples collected from areas of the vineyard with different soil textures and or mineral types.

Establishment of sampling zones or benchmark locations is one way to address the problem of spatial variability. Petiole or blade K level at best can suggest that a deficiency exists or is likely to develop and does not indicate the application rate of K fertilizer needed to prevent a deficiency while avoiding excess K in the fruit. Even though petiole analysis is not highly reliable as a tool for making K management decisions, it does provide some information and can be considered as "the only game in town". Some analytical laboratories and growers have developed their own in-house interpretations for petioles or for leaf blades. Nutrient ratios, sap analysis, and more exotic approaches have not caught on, as far as we are aware.

Soil characteristics determine K supply

In spite of years of crop removal of K, many agricultural soils in California contain large amounts of the element; but much of it is locked up in the mineral matrix and is only very slowly available to plants. Plant-available K is found in the soil solution or is retained on cation exchange sites on soil mineral particles and organic matter. In sandy soils (which generally have low cation exchange capacity), K over time will be leached from soil and must be replaced by fertilization or by slow release from weathering of minerals.

An important phenomenon in soils derived from granitic parent material is potassium fixation. In K fixation, vermiculite (a layer silicate mineral resulting from the weathering of mica) removes K from solution by trapping it on sorption sites within the mineral layers. A portion of K fixed in this manner serves as a slow-release source for plants, but may not become available fast enough during times of high K demand, e.g., in grapes following veraison. Fig. 1 presents a simplified depiction of the genesis of K fixation.

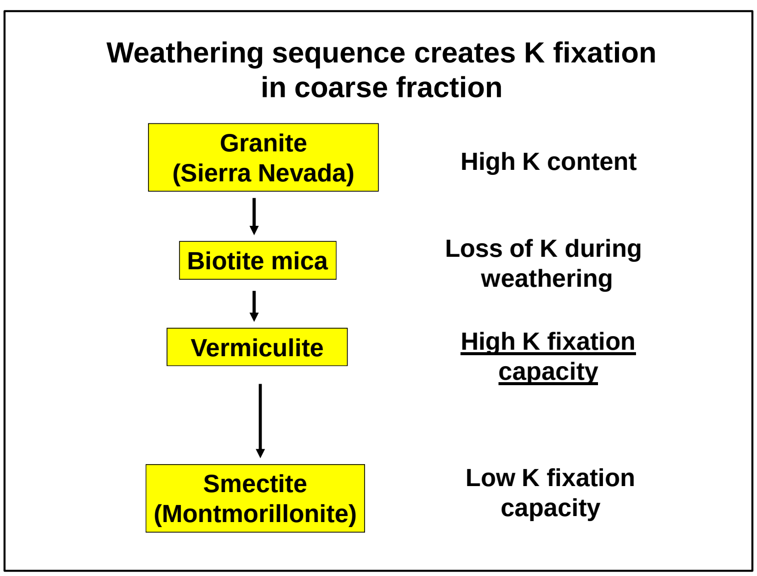

Fig. 1. Simplified schematic of the weathering of granitic rock to vermiculite and smectite and relationship to K fixation.

Soils high in vermiculite are found on the east side of the Central Valley of California, in particular, on landscapes with soils deriving from granitic parent material that are weakly to moderately weathered. Soils formed on more highly weathered landscapes may not fix as much K due to the dominance of non-K-fixing smectitic or kaolinitic minerals.

K fixation in east-side San Joaquin Valley soils has been a problem for cotton growers, and in some cases, K rates of 400 lb K_2O/acre repeated several times may be required to satisfy the K fixation capacity, which has in some cases been measured at several thousand pounds of K per acre in the top 12 inches of the soil profile (Murashkina et al., 2007a). Because vermiculite is a layer silicate mineral, i.e., a clay, K fixation is sometimes found in fine-textured soils. But we have found (cotton-Murashkina et al., 2007b; winegrapes - O'Geen et al., 2008) that in some soils, vermiculite is in the silt and fine-sand size fraction and not in the clay-sized material. This may explain the common observation of significant K fixation in coarse-textured soils.

Soil landscape model in the Lodi winegrape district

Soil K supply characteristics can be inferred from soil survey information. Soils of the Lodi winegrape region are diverse, but differ systematically along an east-west gradient from the foothills to the Delta. Major river systems such as the Sacramento, Cosumnes, Mokelumne and their tributaries deliver sediment derived from contrasting geologic parent materials, which further differentiate soil properties controlling K fixation and tendency for K leaching, including degree of soil development, texture, and mineralogy.

Our study of the soils of the Lodi district began in 2006. Based on soil profile analyses from 141 locations in 36 vineyard blocks, we have grouped the soils of the district into seven regions based on texture and likely parent material source (O'Geen et al., 2008; Southard et al., 2009). The soil groupings are summarized here with comments regarding the success of the model in predicting K fixation.

<u>Region 1: Fine-textured basin and basin rim soils derived from Calaveras, Cosumnes, and Mokelumne River alluvium. Example -Stockton clay soil.</u>

The area of such soils in winegrape production is not extensive. These soils are dominated by smectitic (non-K fixing) clays, but characterization is complicated by the distribution of older underlying strata that can fix K.

<u>Region 2A: Medium- and coarse-textured soils on young fan deposits, flood plains, and stream terraces. Parent materials are Mokelumne or Cosumnes River from dominantly granitic rocks. Example - Columbia soil.</u>

These are important winegrape soils and tend to fix K.

<u>Region 2B: Same landscape position as 2A but fine-textured on Calaveras River alluvium. Example – Archerdale soil</u>.

These do not fix K, but stratigraphy can produce exceptions.

<u>Region 2C: Same landscape position as 2A but coarser even than 2A. Example – Tokay soil.</u>

These are important for viticulture in the district and tend not to fix K.

<u>Region 3: Well developed soils on low, moderately old terraces. Parent materials are Mokelumne or Cosumnes river alluvium from dominantly granitic rocks. Example – San Joaquin, a hardpan soil.</u>

These are important winegrape soils in the district. These almost always fix K and have low exchangeable K except in the top 20 cm.

Region 4: Well-developed, highly weathered soils on high, old dissected terraces. Parent materials are Mokelumne or Cosumnes river alluvium from a mixture of granitic, metamorphic, and volcanic rocks. Example - Redding gravelly loam (hardpan soil).

These soils are important for viticulture in the district. K fixation is inconsistent. Possibly “true Redding soils” do not fix K. Soil survey in this part of the district was not done in as much detail as needed for evaluating this. Also more research is needed to understand the influence of stratigraphy and hillslope soil-forming processes.

Region 5: Undulating volcanic terrain of the far eastern portion of the district. Parent materials are residuum and colluvium from andesitic volcanic rocks. Example – Pentz soil.

These soils have high exchangeable K levels and do not fix K except in a few cases in the deeper layers.

This classification can aid landowners in rootstock selection, in delineation of soil or petiole sampling zones, and in selecting an adequate, but not excessive, rate of K fertilizer.

K fertilizer vineyard experiments

We have established field experiments in drip-irrigated vineyards to determine whether K fertilizer requirement differs in K-fixing and non K-fixing soils. In 2009, we established replicated K fertilizer rate experiments in two commercial Syrah vineyard blocks, one on a San Joaquin soil that shows moderate to strong K fixation and low ammonium acetate extractable K and the other on a Tokay soil with high soil test K and no K fixation. K treatment rates in 2009 were 0, 30, 60, and 90 lb K_2O/acre. K fertilizer (potassium thiosulfate, 0-0-25) is being applied either on the ground directly under drip emitters or through the drip system. Shutoff valves on drip lines are used to prevent grower fertilizer K from confounding treatment effects. In 2010, we started similar K fertilizer experiments in two more commercial vineyards having K-fixing soil – a Pinot Noir and a Chardonnay block. Fruit yields and berry K content so far do not show any treatment differences, and it may require several years to establish K deficiencies on the low-K treatments in these experiments. Soil test K and K fixation are shown in Table 1.

Table 1. Pre-treatment soil test K and K fixation values in Lodi district winegrape K fertilizer trial sites.

	Soil test K	K fixation
Depth, inches	----------- mg/kg soil ------------	
<u>Site 1.Tokay, non-K fixing soil</u>		
0-12	213	0
12-24	117	0
24-36	86	5
<u>Site 2. San Joaquin, K-fixing soil</u>		
0-8	133	0
8-16	62	126
16-24	59	161
<u>Site 3. Sailboat, K fixing soil</u>		
0-12	78	160
12-24	57	394
24-36	64	468
<u>Site 4. Montpellier-Cometa, K fixing soil</u>		
0-12	57	19
12-24	51	106
24-36	58	206

Soil test K by normal neutral NH_4OAc extraction. K fixation by method of Murashkina et al. (2007a).

Literature Cited

Christensen, L.P., A.N. Kasamatis, and F.L. Jensen. 1978. Grapevine nutrition and fertilization in the San Joaquin Valley. Publication 4087. Division of Agriculture and Natural Resources. University of California. Oakland, CA.

Davies, C., R. Shin, W. Liu, M.R. Thomas, and D.P. Schachtman. 2006. Transporters expressed during grape berry (*Vitis vinifera* L.) development are associated with an increase in berry size and berry potassium accumulation. J. Exp. Botany. 57(12):3209-3216.

Harbertson, J.F. and E.D. Harwood. 2009. Partitioning of potassium during commercial-scale wine fermentations and model wine extractions. Am. J. Enol. Vit. 60(1):43-49.

Klein, I., M. Strime, L. Fanberstein, and Y. Mani. 2000. Irrigation and fertigation effects on phosphorus and potassium nutrition of wine grapes. Vitis 39(2):55-62,

Kodur, S., J.M. Tisdall, C. Tang, and R.R. Walker. 2010. Accumulation of potassium in grapevine rootstocks (*Vitis*) grafted to 'Shiraz' as affected by growth, root-traits and transpiration. Vitis 49(1):7-13.

Lambert, J.J., M.M. Anderson, and J.A. Wolpert. 2008. Vineyard nutrient needs vary with rootstocks and soils. Calif. Agric. 62(4):202-207.

Mpelasoka, B.S., Schnachtman, D.P., M.T. Treeby, and M.R. Thomas. 2003. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Australian Journal of Grape and Wine Research. 9:154-168.

Murashkina, M.A., R.J. Southard, and G.S. Pettygrove. 2007a. Potassium fixation in San Joaquin Valley soils derived from granitic and nongranitic alluvium. Soil Sci. Soc. Am. J. 71:125–132.

Murashkina, M.A., R.J. Southard, and G.S. Pettygrove. 2007b. Silt and fine sand fractions dominate K fixation in soils derived from granitic alluvium of the San Joaquin Valley, California. Geoderma 141(3/4):283-293.

O'Geen, A.T., S. Pettygrove, R. Southard, H. Minoshima, and P. S. Verdegaal. 2008a. Soil-landscape model helps predict potassium supply in vineyards. Calif. Agric. 62(4):195-201.

Ruhl, E.H., P.R. Clingeleffer, P.R. Nicolas, R.M. Cirami, M.G. McCarthy, and J.R. Whiting. 1988. Effect of rootstocks in berry weight, pH, mineral content and organic concentrations of grape juice of some wine varieties. Austr. J. Exp. Agr. 28:119-125.

Southard, Randal, H. Minoshima, A.T. O'Geen, and G.S. Pettygrove. 2009. Soil mineralogy and potassium supply in Lodi winegrape district soils. Abstract 55633. American Society of Agronomy, Soil Science Society of American annual meeting abstracts. http://a-c-s.confex.com/crops/2009am/webprogram/Paper55633.html

Wolpert, J.A., D.R. Smart, and M. Anderson. 2005. Lower petiole concentration at bloom in rootstocks with Vitis berlandieri genetic backgrounds. Am. J. Enol. Vitic. 56(2):163-169.

Improving Nitrogen Use Efficiency in Lettuce Production

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Introduction

Nitrate loss from agricultural production on the Central Coast is an increasing concern due to the issuance of a draft Agricultural Order in November, 2010 by the Central Coast Regional Water Quality Control Board (CCRWQCB). The CCRWQCB has discussed proposing a 10 ppm nitrate-N standard for nitrate losses from surface and groundwater from vegetable farming operations. Monitoring carried out by the Cooperative Monitoring Program (CMP) of surface waters throughout the coastal lettuce production region have indicated that nutrient loads are commonly out of the acceptable range (Schmidt and Green, 2008). The 2008 spike in fertilizer prices and growing acceptance by growers of the eventuality of fertilizer regulations have spurred grower interest in ways to more efficiently utilize applied fertilizer. In order to comply with the Agricultural Order, growers will need to reduce the load of applied nitrogen fertilizer and implement nutrient management strategies that reduce the loss of nitrate to leaching to groundwater and losses to surface runoff. The new restrictions are made difficult due to the nature of the crops and production system for cool season vegetables which include: 1) shallow rooted crops, 2) intensity of production system (double cropped), 3) demanding crop quality standards, 4) low cost of fertilizer in comparison with overall production costs and crop value (Smith et al 2009), 5) inefficiencies in irrigation applications (Cahn and Smith 2009), and 6) lack of deep-rooted winter rotational crops which can scavenge residual soil nitrate. In spite of these challenges, there are techniques that growers can utilize to increase the efficiency of applied nitrogen and to reduce losses of nitrate to the environment.

Nitrogen Cycle of a Lettuce Production Field

Monterey County vegetable production fields have higher levels of organic matter than soils in the interior of California. Soil organic matter levels range widely depending on soil type and location in the valley, but generally fall between 0.7 to 2.0%. Mineralization of nitrate from soils with these levels of organic matter can range from 0.5 to 2.0 lbs of N/A/day for a 60 day crop, which can provide a substantial amount of N needed for a developing lettuce crop. Total uptake of N by a mature lettuce crop varies from 110 to 140 lbs N/A with higher amounts taken up in 80-inch bed plantings with six seedlines. One of the difficulties encountered in proving the N uptake needs of lettuce is that over 90% of the N uptake occurs in the last 30 days of the crop (Figure 1). As a result, even though total amount of N needed by the crop is moderate, daily crop uptake can exceed 4.0 lbs/A/day. Growers supply crop N needs by making sidedress applications or injections to drip irrigation systems at thinning (app. 30 days after seeding). The quantity applied varies from 40 to over 80 lbs of N; thinning applications are generally followed by one or more subsequent sidedress applications.

Mid-season nitrogen applications provide the quantity of nitrogen required by the crop during the critical growth phase. The amount of fertilizer needed to apply can be estimated by use of a nitrogen test. In general, if residual soil nitrate values are greater than 20 ppm there is adequate nitrogen available in the soil for a period of time (Breschini and Hartz, 2002). The use of a presidedress soil test is the most effective tool for reducing the load of nitrogen to lettuce production fields during the growing season. This is particularly true for the second crop of lettuce. The reason is that typically 150+ lbs N/A are applied to grow the first crop which is more than the crop utilizes, resulting in a buildup of soil N levels from applied fertilizer. In addition, approximately 80 lbs/A are removed in the harvested product which is only 55-65% of N taken up by the crop. The N in these crop residues are quickly mineralized in warm, moist soils leading to a further increase in residual soil nitrate levels. This residual nitrate can be measured and accounted for in the second crop fertilizer programs. In five large-scale commercial studies conducted in 2008-2009, we utilized a nitrate quick test as a best management practice (BMP) to measure residual nitrogen prior to the first sidedress application and adjust fertilizer applications accordingly; on average we were able to reduce the amount of applied N by 55 lbs/A (Table 1). There were no differences in yield between the grower standard and the BMP practice in the commercially harvested strips (width of the harvest machine by length of field) (Table 2).

Reducing nitrate leaching

Due to the negative charge of the nitrate molecule, it is highly mobile in soil water. Irrigation applications in excess of crop demand and water holding capacity of the soil can move nitrate below the root zone. Therefore nitrogen management is closely linked to irrigation management. In the same large-scale trial referred to above, we managed water application in the BMP plots by use of CIMIS evapotranspiration (ET) data and compared those with the grower standard irrigation practices. Over five trials we applied 2.5 inches less irrigation water (Table 3). We monitored nitrate leaching with suction lysimeters which were placed at two feet deep and estimated the amount of nitrate leaching at one site during the germination phase. At this site where the BMP germination irrigations were managed based on CIMIS ET data, less nitrate was leached than in the standard practice treatment (Table 4).

Lettuce crops only transpire 7-8 inches of water to mature the crop and the levels of nitrate in the soil water need to be in the range of 40-50 ppm nitrate-N to ensure that sufficient N is absorbed by the lettuce plant to maximize yields. The best way to keep high-nitrate soil water from leaching from the root profile is by careful water management.

End of season nitrate management

At the end of the growing season (e.g. October-November) soil nitrate levels can rise to due to the presence of unutilized nitrogen fertilizer and mineralization of crop residues and soil organic matter (Smith and Schulbach, 1997). At this point in the growth cycle, the ideal nitrate management scenario would include a deep-rooted winter rotational crop such as winter wheat or sugar beets. However, these two crops disappeared from the mix of viable rotational crops in the Salinas Valley over 30 years ago due to high land values. As a result, there are frequently large pools of nitrate in the soil at the end of the growing season that are at risk of leaching from winter rains. Cereal cover crops have the ability to absorb 150-200 lbs of N from the soil and maintain it in the crop biomass (Smith, in press). However, due to intensive planting schedules in spring, growers need to keep the ground fallow over the winter so that it is ready to plant when weather permits and as a result, only 5% of the vegetable ground is planted to winter cover crops. Low-residue cover crops offer an alternative cover crop strategy that can provide some of the benefits of cover crops, but that decompose rapidly prior to planting the vegetable crop thereby not posing a residue problem. Low-residue cover crops also increase infiltration and reduce sediment loss from fields (see http://www.youtube.com/watch?v=k0oVVJ_BA7s). However, in the 2009-2010 trial, a low residue cereal rye cover crop only absorbed about 70 lbs N/A which is less than a full-term cover crop (Figure 2). As a result, low-residue cover crops may only provide significant reductions in nitrate leaching in soils with low to moderate levels of nitrate.

Summary

Cool season vegetable production on the Central Coast has significant challenges to effective nitrogen management. However, the pre-sidedress nitrate quick test and careful irrigation management provide significant tools for reducing nitrogen loading in fields during the production season. Low residue cover crops are a potential tool for reducing nitrate leaching in soils with low to moderate levels of soil nitrate.

Figure 1. Nitrogen uptake by lettuce over the growing season.

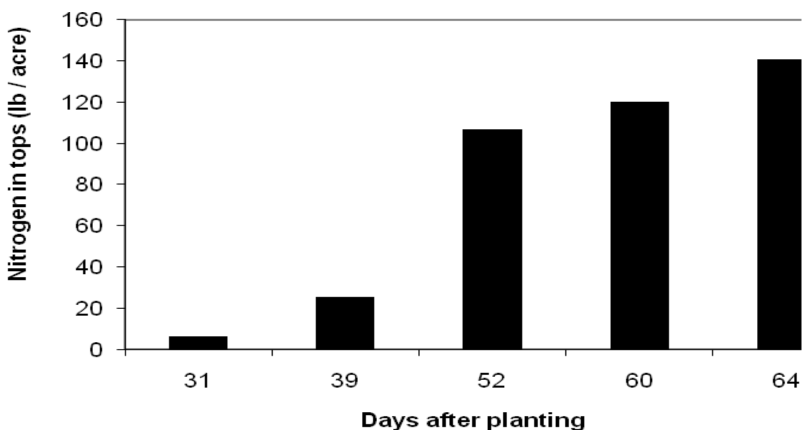

Figure 2. Pattern of uptake of nitrogen and decomposition of residue of two low-residue cover crop species following application of glyphosate on January 14, 2010.

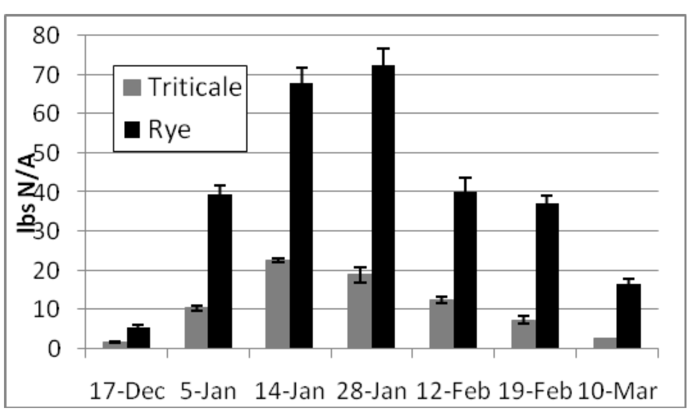

Table 1. Applied nitrogen fertilizer and soil nitrate levels in BMP and grower standard treatments, and fertilzer cost savings at trial sites.

Trial	Total Applied Nitrogen (lbs N/acre) Standard	Total Applied Nitrogen (lbs N/acre) BMP	N Fertilizer Reduction (lbs N/acre)	Fertilizer Cost Reduction ($/acre)[1]	Mean Soil Nitrate (over season) (ppm NO3-N) Standard	Mean Soil Nitrate (over season) (ppm NO3-N) BMP	Total N Uptake at Harvest (lbs N/acre) Standard	Total N Uptake at Harvest (lbs N/acre) BMP
Trial 1	248	110	139	83	33.3	47.0	134	142
Trial 2	77	65	12	7	18.3	19.5	149	133
Trial 3	200	154	46	28	19.5	20.4	86	93
Trial 4	180	134	47	28	18.7	17.7	165	173
Trial 5	175	144	31	18	41.3	26.9	120	119
Average	176	121	55	33	26.2	26.3	131	132

[1] nitrogen fertilizer valued at $0.60/lb

Table 2. Commerical and small plot yields of BMP and grower standard lettuce treatments.

Trial	small plot harvest: Total CFR[1] Yield (tons/acre) Grower	small plot harvest: Total CFR[1] Yield (tons/acre) BMP	small plot harvest: BMP relative to Standard (%)	commercial harvest: Total CFR Yield (tons/acre) Grower	commercial harvest: Total CFR Yield (tons/acre) BMP	commercial harvest: BMP relative to Standard (%)
Trial 1	27.3	27.8	102	21.6	21.4	99
Trial 2	26.5	23.0	87	13.9	14.0	100
Trial 3	12.1	10.5	87	--	--	
Trial 4	38.6	40.2	104	30.0	29.5	98
Trial 5	14.4	14.8	103	9.0	9.0	101
Average	23.8	23.2	96	18.6	18.5	100

[1] CFR = Cored for region

Table 3. Applied water in BMP and grower standard lettuce treatments during germination and post germination.

Trial	Standard Total Applied Water (inches)	BMP Total Applied Water (inches)	Estimated Crop ETc (inches)	Irrigation requirement [1] (inches)	Water use reduction (%)	Energy Savings[2] ($/acre)
Trial 1	17.7	14.7	10.1	13.4	17	15.5
Trial 2	9.9	8.7	7.6	8.9	12	7.6
Trial 3	19.4	11.9	6.7	8.7	39	18.1
Trial 4	10.7	10.4	7.0	8.4	3	1.2
Trial 5	10.9	10.1	6.1	7.6	7	3.2
Average	13.7	11.2	7.5	9.4	16	9

1. irrigation requirement = ETc/DU; DU = distribution uniformity of the irrigation system

2. assumes energy costs of $0.15/kWhr, operating well depths of 75 feet for south county trials, and 150 feet for north county trials

Table 4. Estimated nitrate nitrogen losses due to leaching during germination of lettuce: Trial 2, July 10 to July 24, 2008

Management Treatment	Applied Water[1]	Crop ET	Soil Moisture Storage	Percolation	NO3-N concentration in leachate	Nitrogen loss by leaching	Value of Fertilizer lost [2]
	----------------	inches	----------------		ppm	lb/acre	$/acre
BMP	2.4	1.2	0.0	1.2	116.4	31.4	18.85
Standard	3.5	1.2	0.3	2.1	104.9	49.5	29.67

1 July 10 - July 24, 2008

2 N fertilizer value = $0.60/lb

Literature Cited

Breschini, S.J and T.K. Hartz. 2002. Presidedress soil nitrate testing reduces nitrogen fertilizer use and nitrate leaching hazard in lettuce production. HortScience 37(7): 1061-1064.

Cahn, M. and R. Smith. 2009. Optimizing irrigation and nitrogen management in lettuce for improving farm water quality, Northern Monterey County Mid-term Report, Monterey County Community Foundation. NPS Grant Mid-term Report. pp. 6.

Schmidt, K. and S. Greene. 2008. 2005-2008 Water Quality Report, Central Coast Conditional Waiver Cooperative Monitoring Program.

Smith, R.F and K. Schulbach. 1997. Development and promotion of nitrogen quick tests for determining nitrogen fertilizer needs of vegetables. Proceedings of the California Plant and Soil Conference, pages 51-52.

Smith, R.F., K. Klonsky and R. DeMoura. 2009. Sample cost to produce romaine hearts. DANR publication LT-CC-09-2, http://coststudies.ucdavis.edu/files/lettuceromcc09.pdf.

Smith, R.F. In press. Cover crops for nutrient management in organic strawberry production on the central coast. In Organic strawberry production manual, Editors: Koike, S.T., C. Bull, M. Bolda and O. Daugovish. DANR Publication.

What You Should Know About Soil Test Reports

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Introduction

Soil tests are developed for the purpose of identifying the physical, chemical and/or nutrient character of the soil with the large majority of tests being conducted on agricultural soils. Although often focused on plant nutrition, the soil test can also provide helpful information related to the physical and chemical characteristics of the soil. For the analysis of pH, salinity, B, Cl, SO4, Ca, Mg, and Na, the soil tests are performed on soils that have been saturated with distilled water and left to stand for a specified period before applying suction filtration to obtain what is known as a saturated paste extract. For N, P, and K, extracting solutions other than water are typically used. Most importantly, results from the soil test procedure must have a good correlation with field performance.

A reputable soils lab will have good knowledge about all aspects of the soil test from the initial sampling methodology, to the storage and processing of the sample and right on through to the specific laboratory procedure. A good soils lab will provide results that are highly reproducible, follow established laboratory procedures, and use appropriate and well-maintained, analytical equipment. Equipment calibration is often a key element to keep measurements both accurate and precise. Ideally, the laboratory selected uses approved and well-established procedures that are well recognized in the industry.

Before conducting the sampling in the field, it is wise to have a clear picture of what it is you are trying to accomplish with a soil test. Having a clear goal in mind can save a lot of time and expense in the sampling, analysis and interpretation phases of the test. Some soil tests are conducted for predictive purposes and are centered upon using the report to estimate future fertilizer or amendment needs. Other tests are considered diagnostic because they attempt to evaluate potential problems including deficiencies and excesses in soils.

In a pre-plant evaluation, analysis of soil texture is recommended and chemical tests such as EC and pH can be very telling to determine if there are major problems with the chemical nature of the soil that may complicate the nutrient picture. For example, pH can influence the availability of some nutrients in soil. However, if the primary purpose is to estimate current soil nitrate levels, there is little reason to request tests such as electrical conductivity (EC) and pH. On the other hand, if it has been a long time since the soil has had these tests, or salinity or pH adjustment is typically needed, then they should be included as they are relatively inexpensive. Plant tissue analysis used together with soil test information can also be a key part to a more complete evaluation of nutrient status and fertilizer recommendations. For most of the major crops grown in California there are critical values for both soil and plant tissue tests that are recommended for optimum plant growth and production. Plant tissue analysis can and has been successfully used to confirm or correct recommendations that were based on earlier soil test results.

Sampling Procedures

The soil sampling approach that is incorporated into the plan will depend on the purpose and nature of the information that is desired. For nutrient analysis it is important to sample the soil volume that the roots will be in contact with and this is generally obtained from surface samples collected in the top 12 to 24 inches. Nutrient concentrations in the surface are generally higher as a result of organic matter decomposition and the tendency for immobile nutrients to reside close to the zones in which they were placed. In the case of more mobile nutrients such as nitrate (NO_3^-), deeper soil sampling may be necessary for crops that are more deeply rooted. Compositing multiple soil cores reduces the risk of collecting non-representative soil samples and increases the chance that the sample is representative of mid-range conditions within the field. This type of sampling approach is more desirable when you are trying to characterize an entire field that does not have widely differing soil conditions types over a significant portion of the acreage. In the case of fields that have distinct areas where soil characteristics differ, it is best to separate those areas and sample each area separately to better understand the variable nature of the soils being evaluated. Generally speaking, a single soil sample should include a minimum of 10 to 15 field cores to represent the desired area and zone.

Opportunities for sample contamination can and should be minimized by developing good sampling methods, by proper use of the sampling device and by using appropriate sample storage methods. Depending on the time required for analysis, soils are often dried and stored under low temperatures to minimize the chances for microbial activity to take place and possibly impacting the soil test results. The use of proper soil containers for collection, compositing and storage will also help to provide a representative sample that is free from contamination. It cannot be over-emphasized that interpretation of the soil test result can be largely dependent upon the soil sampling procedures employed. In other words, the accuracy of the test is only as good as the sample provided.

Saturated Pastes

Saturated soil pastes and their extracts are most commonly used to determine soluble salt content and the relative nutrient content of the soil in terms of plant availability. Determinations from soil paste extracts are effective in identifying the solubility and presence of numerous water- soluble salts and nutrients. The relative solubility and availability of calcium, for instance, is a key criterion in understanding the physical stability of soils. Water soluble contents of other important salts such as magnesium, sodium, chloride, sulfate, boron, and carbonates provide good information on the balance of soluble soil salts. At lower concentrations, salts of nitrogen, potassium, and many of the micronutrients can be obtained by analyzing soil paste extracts although other extraction methods may be preferable.

Some mineral salts are held more tightly by the soil in aqueous solutions and require alternatives to water extracts to better approximate plant availability. Potassium ions for instance, can be held in available and semi-available forms on the exterior of clay minerals, or can be found in higher concentrations in fixed forms that are unavailable to the plant. To estimate crop responses, an ammonium acetate extraction test is generally used for this purpose and best approximates the likelihood for a crop response.

By virtue of the method by which a saturated soil paste is developed, information on the water holding characteristics and soil texture can be inferred. The saturation percentage (SP) is determined from measuring the water content of a saturated paste and is expressed as grams of water per 100 grams of soil. Its value can be used to estimate soil water storage, soil clay content, and the cation exchange capacity of the soil. An estimate of the volumetric water content at field capacity can be obtained by dividing the SP by 2 and the permanent wilting point of the soil estimated by dividing the SP by 4. These values are often important in determining the total water available to the plant following an irrigation event.

Also available from some labs are alternative methods for determining soil salt constituents including the 1:1 and 1:2 soil extract methods.

Chemical Properties

Evaluating the chemical properties of mineral soils is partially accomplished through analysis of the major soil constituents as discussed above, and by examination of the hydrogen ion as determined by the measurement of soil pH. Soil pH is one of the primary soil tests because of its ability to modify nutrient availability in soil. Because pH is the negative log of hydrogen ion concentration, low pH values indicate high hydrogen ion concentrations and high pH values indicate low hydrogen ion concentration. Many plant nutrients have narrow pH ranges in which they are optimally available for plant uptake.

The availability of phosphorus is strongly pH dependent with optimum availability ranging between pH 6 and 7. Many of the important micronutrients such as zinc and iron have lower optimum pH values and are most available in the range from 5.5 to 6.5. However, biological activity is favored by neutral pH environments that allow important processes to occur such as nitrification, nitrogen fixation and decomposition of readily available organic matter. And mineral toxicities are generally avoided when soil pH levels are above 6.0, thus a pH at or slightly above 6.5 is often recommended. Soil pH can also influence the charge of soil particles and therefore their ability to attract and store nutrient and salts.

Soil Nutrient Analysis

Many growers consider the soil test to be a critical part of the determination of fertilizer need and use by crops. A good soil test will be representative of the plant-available nutrients in the soil and allow a grower to develop a fertilizer recommendation for fulfilling the crop need. Applying too little fertilizer can have devastating consequences on productivity, while applying too much fertilizer reduces farm profitability, can reduce crop quality and with some nutrients, increase the opportunity for environmental degradation.

The ability of a crop to take up soil nutrients can vary just as the crop's need for a specific nutrient will vary. Soil test interpretive guides are available from multiple sources including University of California publications for the major California crops and from many of the private soil testing laboratories. These sufficiency levels were developed over many years and on many different soil types and they represent a type of risk assessment to the grower. These interpretive guides often evaluate the likelihood for a fertilizer response at a given soil test level. Oftentimes the guides are divided into soil test values that represent a high, medium or low probability of having a response to fertilizer applications.

But what is not included in the test, is the additional understanding that is needed to make the most of the soil test result and its interpretation. Once a field has been identified as deficient, care must be taken to apply the most appropriate form of the nutrient to be applied, the timing of the fertilizer, and the application method that will provide the best results from both a production and environmental standpoint.

Interpreting soil nutrient test results and making recommendations based on those results should be accomplished using supporting information such as recent crop rotations and yields, fertilizer application history, previous soil test results, water quality and plant tissue tests. Understanding the recent history of a field in these terms can be particularly useful in identifying parts of the field that are underperforming and assist in identifying the reasons for that underperformance.

Documentation

It is not uncommon that the soil test result is evaluated without regard to this supporting information. It should be strongly emphasized that this information and any field documentation be considered in the total analysis. Good field recommendations that include past documentation can assist in showing long or short term soil trends that can assist in making the most appropriate recommendation. Field notes that include information on anticipated crop yield, soil type and field variability issues can be used in making a recommendation. Fields with high soil and nutrient variability should be considered as candidates for precision applications of nutrients and/or soil amendments thereby creating even greater opportunities to optimize the value of a soil test. Soil mapping technologies such as the VERIS and EM-38 systems can provide detailed soil maps to determine the degree of spatial variability in a field and the potential need for variable rate application.

How to Read a Tissue Test Report

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American Society of Agronomy
California Chapter

Session II
Soil Salinity and Quality

Session Chairs:
Steve Grattan
Joe Fabry

CV-SALTS – A Stakeholder Program for Salinity Management and the Critical Role it plays in California's Future and Water Supplies

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Background

Managing salinity and nutrients is critical to all users of the waters of the Central Valley. These waters are used directly as drinking water, for commercial and industrial uses and for aquifer recharge throughout much of California. Water from the Central Valley is used directly by approximately 25 million residents of California. The quality and reliability of this water supply is of critical importance to all users including the environment shown by the figure below.[1]

Indirectly, Central Valley waters are utilized throughout all of California and around the globe. Agricultural production requires a significant percentage of Central Valley waters and its exports are exported to every state and almost every country in the world. Over 50% of almonds, pistachios, walnuts, and plums produced are exported to the European Union and Japan. Over 50% of cotton is exported to China and Turkey. Additionally, Canada is a significant importer of Central Valley produce and California's number one export country in 2007. Many agricultural products that consume significant Central Valley water are majority export crops. In all, 28% of all crops produced in 2008 were exported.[2] Therefore managing salinity and nutrients is critical to all Californians and users of Central Valley waters worldwide.

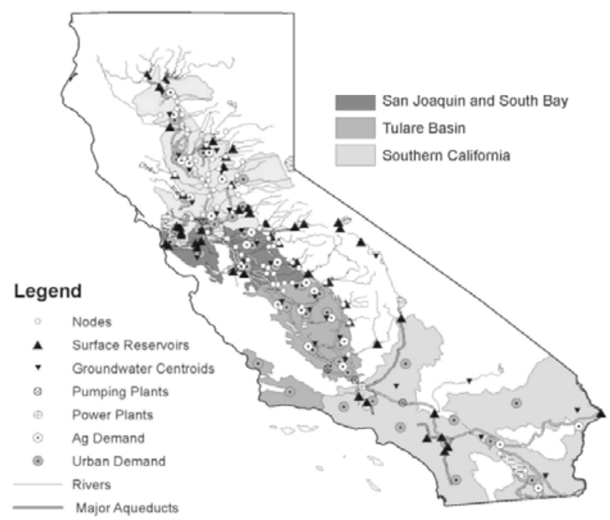

Figure 1 Water Supply and Usage from CALVIN Model

Why is Salinity an Important Issue for Users of Central Valley Water?

California must have a reliable supply of quality water. Elevated levels of salinity in drinking or irrigation water can significantly reduce utility of the water and reduce yields for many crops. Eventually salinity may result in the abandonment of farm lands or costly treatment for drinking water once used to meet discharge limits. In addition to urban areas, food processors, dairies, and wineries are also directly affected. As salinity levels rise in surface waters and groundwater in the region, users will be subject to much more stringent wastewater discharge permit standards that may be difficult or impossible to attain in an economic manner.

How big is the Salinity Problem?

Salinity is a problem that tends to grow relatively slowly, but eventually can lead to disastrous results. Over 15.5 million tons of salt are brought into or mobilized in the waters of the Central Valley of California each year. Because there are few outlets for salt to move out of the Valley they continue to build up in the soil and waters of the region. This imbalance cannot be sustained over the long term and threatens the long-term future of agriculture and food processing. A recent study found that if nothing additional is done to address salinity; the impact on the economy will be significant. The researchers estimated that, comparing economic conditions in the year 2030 with 2005 levels, output from irrigated agriculture could decline by $1.2 billion due to higher salinity levels, and the output from food processors and dairies may be $133 million and $159 million lower respectively. These lower levels of agricultural output alone could reduce aggregate employment and income across most parts of the Central Valley.[3]

Where Does All the Salt Come From?

The salt comes from natural sources and human activity. A large portion of the salts are brought into the Central Valley with imported water. Salt and nitrate also enter the system in fertilizers, chemicals, detergents, waste products and various other sources. Evaporation and consumptive use both result in water being removed and salts being left behind. To better identify salt and nutrient sources CV-SALTS has a Pilot Implementation Study ongoing to pioneer methodology and demonstrate important sources in the Central Valley.[4]

CV-SALTS a Stakeholder Led Approach

While salt and nutrients are critical to all users of Central Valley waters; in-valley users that rely on the water directly or those who discharge to Central Valley waters are the most affected. To help move the basin plan revision process forward, CV-SALTS (Central Valley Salinity Alternatives for Long-Term Sustainability) was formed by the State Resources Control Water Board (SWRCB) and Central Valley Water Board (CVRWQCB) to work with all stakeholders to develop a salt management plan and update the regional basin plans. Affected users and groups lead CV-SALTS with the SWRCB, CVRWQCB and other partners. The affected users have also formed the Central Valley Salinity Coalition (CVSC) to bring all affected users of Central Valley waters together to provide the policy and science needed to develop and implement management alternatives addressing these problems. The organization of these groups under CV-SALTS is documented in a Memorandum of Agreement. [5]

The focus of all the work is on developing policies based on proven science and sound economics that are consistent with the Porter Cologne Act and Clean Water Act. The CV-SALTS initiative was modeled after a similar effort in the Santa Ana region that brought together a diverse set of interests to develop a comprehensive salt management plan.

What is the Central Valley Salinity Coalition?

The Central Valley Salinity Coalition (CVSC) is a 501 C-6 non-profit coalition of public agencies, businesses, trade associations, cities and counties, and other partners.[6] CVSC was formed in July 2008 to organize, facilitate and fund the efforts needed for the efficient management of salinity in the Central Valley. CVSC closely coordinates its activities with CV-SALTS. This broad Coalition of users of Central Valley water lead to this important effort.

Why Does CV-SALTS Need Funding? How Much is Needed?

Salinity is a large and complex issue and it will require substantial resources to determine the scope of the problem, explore options for mitigating or removing salt from the Valley, and to develop a comprehensive long-term plan of action. Central Valley Water Board staff and committee members estimate that the total cost of collecting the data, conducting the necessary studies, vetting the analysis with stakeholders, and revising the basin plans will require more than 10 million dollars over the next 5-6 years.[7] The SWRCB and CVRWQCB are contributing significant resources, along with contributions from the stakeholders participating in the Central Valley Salinity Coalition. However, the funds raised from these sources will likely not be sufficient, so water supply and agricultural interests need other government agencies to engage and help contribute funds to solving this important issue.

Coordination with other Regulatory and Non-Regulatory Efforts

The Executive Committee has identified over 60 linked, related, interdependent, and associated programs, projects and efforts within the Central Valley.[8] Beyond these there are hundreds of permits and waste discharge requirements that are dependent on the salt and nutrient sections of the Basin Plan. The programs are diverse, from the Bay Delta Conservation Plan to the Irrigated Lands Program and from the San Joaquin River Restoration to the Statewide Recycled Water Policy. The Executive Committee with the Technical Advisory Committee is condensing these into a draft matrix that identifies the coordinating contacts and principal effects of the efforts. This will be used to coordinate and cooperate with these efforts.

California's Future Water Supply is Recycled Water

The only drought-proof source of new water for much of the Central Valley's future is recycled water. Recycled Water increased salts when reused. The CV-SALTS process is the program process the Regional Board has approved for the development of recycled water policy Salt and Nutrient Management Plans (SNMP) as required by the SWRCB in the Recycled Water Policy in January 2009.[9] Project proponents of any recycled water project for which a SNMP is beneficial shall work through CV-SALTS. The Executive Committee has established the process below for proponents or stakeholder groups working on recycled water projects or management plans:

1. Lund, Jay; Howitt, Richard, et al. University of California Davis, Water Management Lessons for California from Statewide Hydro-economic Modeling Using the CALVIN Model *11/*3/2009 - http://cee.engr.ucdavis.edu/CALVIN/

2. University of California Davis, Agricultural Issues Center, California Agricultural Exports 2007, with updates for 2008, Last Accessed 12/15/2009 http://aic.ucdavis.edu/pub/exports.html

3. Howitt, Richard, University of California Davis, Economic Impacts of Central Valley Salinity for CV-SALTS March 2009 – Last accessed 12/15/2009 http://www.swrcb.ca.gov/rwqcb5/water_issues/salinity/programs_policies_reports/econ_rpt_final.pdf

4. Larry Walker Associates for CV-SALTS, Salt and Nitrate Source Pilot Implementation Study, 12/21/2009 - http://www.cvsalinity.org/index.php/component/content/article/18-events/60-admin

5. Central Valley Salinity Coalition, Memorandum of Agreement among the State Water Resources Control Board, Central Valley Regional Water Quality Control Board and Central Valley Salinity Coalition 12/10/2009 - http://www.cvsalinity.org/index.php/agendas/doc_download/92-cv-salts-memorandum-of-agreement-moa

6. Central Valley Salinity Coalition, Coalition Membership Update 12/01/2009 – Last accessed 12/19/2009 http://www.cvsalinity.org/index.php/background/1-background/6-membership

7. Central Valley Salinity Coalition, CV-SALTS Executive Committee, Work Plan Outline with Cost and Schedule Estimates, 07/2009 - http://www.cvsalinity.org/index.php/documents/doc_download/225-cv-salts-workplan-outline-with-cost-schedule

8. Central Valley Salinity Coalition, CV-SALTS Executive, Committee Central Valley Salinity and Nitrate Coordinated Programs, 05-2009 – http://www.cvsalinity.org/index.php/documents/doc_download/93-salinity-program-coordination-matrix-

9. State Water Resources Control Board, Recycled Water Policy, 01/2009 - http://www.swrcb.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf

Conclusion

The CV-SALTS Initiative is a large and complex multi-year program involving hundreds of stakeholders and requiring significant resources in both planning and implementation. While difficult, no other program offers the opportunities for working collaboratively to reduce duplication of effort, meeting multiple objectives and economically protecting the critical beneficial uses of Central Valley waters.

Re-evaluation of the Soil Salinity Leaching Requirements

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Introduction

All irrigation waters contain salts and, except for nutrients and some specific elements, crops take up nearly pure water for transpiration and most of the salts concentrate in the root zone. Periodic leaching by water to move excessive salts downward from the root zone is required to avoid reduced crop yields. Thus, a combination of irrigation and rainfall must be supplied to provide for both crop transpiration and salt leaching. Application of water greater than the amount required for leaching salts is not desired because nutrients and pesticides are also being leached. The fraction of the amount of applied irrigation and rain water that drains beyond the root zone is defined as the leaching fraction (LF). The term "Leaching Requirement" (LR) has been defined as the minimum LF that is required over a growing season for a particular quality of water to achieve maximum yield of a given crop and has a specific quantitative value.

Clearly an accurate and reliable method of calculating the LR is important for the efficient utilization of irrigation water. An under-estimate would result in yield reduction, and an over-estimate would result in excessive water utilization. The importance of having correct information on the LR became even more critical in California where selenium in agricultural drainage waters in the western San Joaquin Valley causes bird damage. The amount of drainage water produced is directly related to the LF so irrigation practices using a low LF would be a positive approach to partially mitigate the impact of selenium in the drainage waters. However, this approach could salinate the soils to levels that would reduce crop yields if the proposed LF was too low.

Determination of the Leaching Requirement

Crops are recognized to have different degrees of tolerance to salinity that would lead to different values of LR. Extensive research has been conducted in the past to assess crop salt tolerance. Much of that work was summarized for more that 60 agricultural crops by Maas and Hoffman (1977). Now the list has been expanded to over 100 (Grieve et al., 2010). Maas and Hoffman reported salt tolerance information using two coefficients: the salt tolerance threshold value and the percent yield decline per unit increase in salinity beyond the threshold value. The Maas and Hoffman (M-H) coefficients continue to provide the scientific basis for irrigation management guidelines world-wide.

Coefficients were related to the average root zone electrical conductivity of the saturated soil extract (ECe). Plants are expected to respond to the salinity of the water surrounding the root (ECs). Since soils are typically at field capacity or at lower water content during the growing season, it has been commonly assumed that ECs is approximately equal to 2ECe. Maximum yield is expected if the average root zone ECe is equal to or less than the M-H threshold value (ECe*).

Published Leaching Requirement Guidelines

Guidelines developed and presented in Irrigation and Drainage Paper No. 29 by the United Nations entitled, "Water quality for Agriculture" (Ayers and Westcot, 1985) have been used internationally as an estimate of LR. Ayers and Westcot (1985) also presented the following equation developed by Rhoades (1974) as a guideline for calculating LR based on irrigation water salinity and crop salt tolerance.

$$LR = ECw / (5ECe^* - ECw) \qquad [1]$$

where ECw is the electrical conductivity of the irrigation water. Rhoades (1999) presented two graphs showing the linear relationship between average root zone ECe and ECw for LF values between 0.05 and 0.50. These two graphs were reproduced by Hanson et al. (2006) in their handbook entitled, "Agricultural Salinity and Drainage" that was published by the U.C. Division of Agriculture and Natural Resources. One graph was for conventional surface and sprinkler irrigation (UC1) and the other for high frequency irrigation methods (UC2) such as drip. A comparison of these four guidelines will be presented later.

These guidelines that were established several decades ago were based on steady-state conditions. Mathematically a steady-state flow analysis does not include a time variable; whereas, a more complex transient-flow analysis does. Considering a steady-state flow analysis of water and solute, the water content and solute concentration at a given point remains constant with time in a steady-state system and can vary in a transient-state system. In fact, "true" steady-state conditions never exist in the field. Steady-state specifies that applied irrigation water is continuously flowing downward at a constant rate, irrespective of irrigation frequency. In addition, steady-state specifies that evapotranspiration is constant over the growing season. None of these is real. Nevertheless, steady-state analyses often provide acceptable approximations for the more complex transient-state analyses. In deed, until modern computers were developed that rapidly do the mathematical manipulations that are required in a transient-state analysis, only the steady-state analysis was feasible.

Evaluation of the Steady-State Leaching Requirement Guidelines

The University of California Center for Water Resources appointed a workgroup with a charge to answer the question, "Do the current recommended guidelines on leaching requirements (based on steady-state analyses) need to be revised?" This information is not only important to farmers, but also for regulatory agencies that apply or establish salinity standards for water bodies designed to protect agricultural production. This paper reports that the workgroup concludes that the answer to the question is yes. The present guidelines overestimate the LR and underestimate the level of salinity in the irrigation water that can be effectively utilized. A summary of the analysis leading to this conclusion follows.

Transient-State Considerations

The soil water salinity in a field is continually changing with time. The soil salinity at two depths and soil-water potential at one depth as measured in an alfalfa field by Rhoades

(1972) and his Figure 4 is reproduced here. Note that the after irrigation the soil becomes drier (more negative soil-water potential) and the salinity increases. Irrigation rewets the soil and reduces the soil salinity. The cycle is repeated for all irrigations. The transient-state behavior is clearly illustrated.

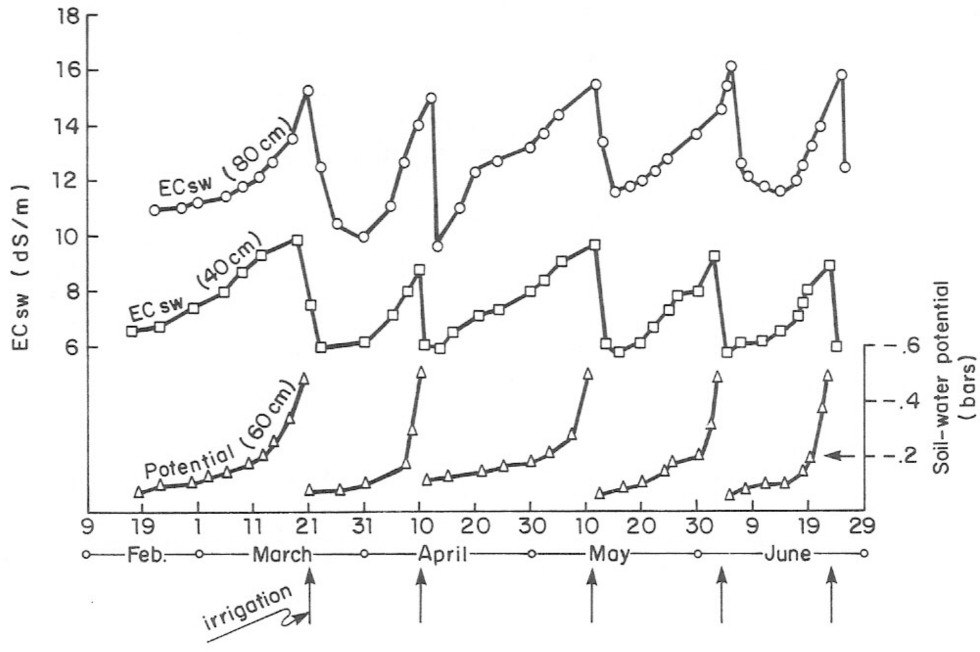

Fig. 4 Change in salinity of soil-water (EC_{sw}) between irrigations of alfalfa due to ET use of stored water (Rhoades 1972)

Advanced computer technology has facilitated the opportunity to develop models based on transient-state analyses. These models allow simulations that include temporal changes in crop, changes in crop salt tolerance through the growing season, water salinity including rain, and the amount of irrigation and rain that are consistent with actual conditions. Several models have been published in the literature. The workgroup developed a matrix to compare various features of the models. Some models have several features that are the same, but each has at least one component that differs from the others.

Comparison of Steady-State and Transient-State Analyses

Letey and Feng (2007) compared results of transient-state analysis using ENVIRO-GRO with steady-state analyses for irrigating corn. The ratio of applied water (AW) to potential evapotranspiration (PET) to achieve maximum yield was determined by each procedure. The results are presented in Table 1 for irrigating corn with water salinity values of 1 or 2 dS/m. The ECe^* for corn grain was assumed to equal 1.7 dS/m (Maas and Hoffman, 1977). All steady-state methods predicted that more water had to be applied to achieve maximum yield as compared to ENVIRO-GRO. The differences were especially great at the higher water salinity.

Table 1. The AW/PET value calculated with ENVIRO-GRO (E-G) and several steady-state models to achieve maximum corn yield when irrigating with water of 1 and 2 dS/m. A&W refers to Ayers and Westcot (1985), UC1 and UC2 refer to guidelines in Hanson et al. (2006), and E-G refers to ENVIRO-GRO (Pang and Letey, 1998).

ECw	A&W	UC1	UC2	Eq 1	E-G
1	1.19	1.19	1.11	1.15	<1.05
2	1.82	1.67	1.75	1.44	1.17

Conclusions

The workgroup (Letey, et al. 2010) concluded that the present guidelines based on steady-state analyses overestimate the leaching requirements and the negative consequences of irrigating with saline waters. This error is particularly large at low leaching fractions. This is a fortuitist finding because irrigating to achieve low leaching fractions is desirable for the purpose of reducing the transport of chemicals that degrade groundwater quality and also provides for a more efficient use of limited water supplies. The feasibility of using saline waters for irrigation is also enhanced. Thus these positive goals can be pursued without an erroneous overestimate of developing soil salination. However, soil salination is still a potentially very negative consequence of irrigation and cannot be ignored.

Literature Cited

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

Corwin, D.L., Rhoades, J.D., Simunek, J., 2007. Leaching requirement for soil salinity control: steady-state versus transient models. Agric. Water Manage. 90,165-180

Feng, G.L., Meiri, A., Letey, J., 2003. Evaluation of a model for irrigation management under saline conditions. I. Effects on plant growth. Soil Sci. Soc. Am. J. 67,71-76.

Grieve,C.M., S.R. Grattan, and E.V. Maas 2010. Plant salt tolerance. In W.W. Wallender and K.K. Tanji (eds). Agricultural Salinity Assessment and Management (2nd edition) ASCE (In Press).

Hanson, B.R., Grattan, S. R., Fulton, A., 2006. Agricultural Salinity and Drainage. Division of Agriculture and Natural Resources Publication 3375. University of California. 164 pp (Revised edition).

Hanson, B.R., May, D.E., Simunek, J., Hopmans, J.W., Hutmacher, R.B., 2009. Drip irrigation increases the profitability of tomatoes in the San Joaquin Valley and may eliminate the need for drainage-water disposal facilities. Cal Agriculture 63,131-136.

Isidoro, D., Grattan,S.R., 2010. Predicting soil salinity in response to different irrigation practices, soil types and rainfall scenarios. Irrig Sci (In Press).DOI:10.1007/s00271-010-0223-7.

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

Maas, E.V., Hoffman, G.J., 1977. Crop salt tolerance – current assessment. J. Irrig. Drainage Div., ASCE 103 (IR2), pp.115-134.
Pang, X.P., Letey, J., 1998. Development and evaluation of ENVIRO-GRO: an integrated water, salinity, and nitrogen model. Soil Sci. Soc. Am. J. 62, 1418-1427.
Rhoades, J.D. 1972. Quality of water for irrigation. Soil Sci. 113:277-284.
Rhoades, J.D., 1974. Drainage for salinity control. In: J. van Schilfgaarde (Ed), Drainage for Agriculture. Am. Soc. Agron. Monograph No. 17, pp.433-462.
Rhoades, J.D., 1999. Use of saline drainage water for irrigation. In R. W. Skaggs and J.van Schlfgaarde (ed.). Agricultural Drainage. Agron. Monogr. 38. ASA-CSSA-SSSA, Madison WI. pp615-657.
Shalhevet, J., Vinten, A., Meiri, A., 1986. Irrigation interval as a factor in sweet corn response to salinity. Agron. J. 78,539-545.

Assessing the Suitability of Water for Irrigation

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Introduction

Water quality assessment to evaluate the suitability of an irrigation water has traditionally (Ayers and Westcot, 1985) considered only salinity and SAR (sodium adsorption ratio). The criteria have been developed from a combination of field observations by experts and short duration column experiments with continuous, saturated water flow. Considering only the effects on soil physical properties, there are a large number of additional variables that need to be considered when evaluating irrigation water. Among these factors are clay mineralogy, oxide content, organic matter content, tillage practices, mode of irrigation water applications, rain, pH and Ca/Mg ratio of irrigation water. In most instances we understand the qualitative impact on soil stability but we lack quantitative data on their impacts and have almost no information on their interactions.

Water Quality Assessment

We have conducted a series of infiltration studies each of season long duration, examining the effects of salinity, SAR, pH, rain, rain interacting with water composition and cover crop. These outdoor container studies include wetting and drying cycles, attempting to simulate a field condition. We have determined that there is greater sensitivity of infiltration rates to SAR than previously considered (Suarez et al., 2006). Decreases in infiltration were observed with any increase in SAR above 0, thus there was no threshold SAR where infiltration first started to be reduced. This is in contrast to existing recommendations and laboratory studies on soil flocculation (in test tubes) where there is a relatively sharp break in the SAR, dependent on salinity, above which a soil does not flocculate in a test tube. Typically, current water quality criteria consider waters below SAR 5 or in some references waters below SAR 15 to be safe from infiltration loss.

We have determined that the reduction in infiltration and thus sensitivity to SAR was greater in the experiments where we cycled between rain events (using a rain simulator) and surface irrigation of water of SAR greater than 0 (treatments in this case were SAR 2, 4, 6, 8 and 10). We also determined that with high rainfall intensity almost the same relative reductions in infiltration with varying SAR occurred in the presence of a cover crop (alfalfa) as with uncropped soil (Suarez et al., 2008). In both of these studies (Suarez et al., 2006; 2008) we observed approximately the same relative decrease in infiltration for a coarse - textured and fine textured soil. Although the relative decreases were comparable, the impact of these decreases is clearly more significant for the finer textured soil, as in arid regions with high evapotranspiration demands water infiltration may already be a limiting consideration for optimal crop production.

Additional experiments have demonstrated that even small increases in pH (pH 7 vs. pH 6) of the irrigation water (with constant SAR and EC) result in decreases in infiltration, and that the greater the increase in pH the greater the decrease in infiltration. (Suarez and Gonzalez, in preparation). These studies are consistent with earlier laboratory studies (Suarez et al., 1984) in which hydraulic conductivity increased with increasing pH in short term saturated flow column experiments. Thus pH, independent of the effect of SAR, is important to predict changes in soil physical properties of arid land soils.

Reductions in infiltration increased with time over the course of the experiments, with a greater separation among the infiltration rates of the various treatments, indicating greater sensitivity to SAR as compared to the short term laboratory column experiments. Based on these experiments, we developed alternative criteria for evaluating the impact of salinity, SAR and also pH on infiltration (Suarez, in press). These criteria are primarily for arid land soils only provide a general assessment.

Modeling Plant Response to Salinity

The UNSATCHEM computer model (Suarez and Simunek, 1997) and the more user friendly SWS model (Suarez and Vaughan, 2001) are utilized to assist in management decisions related to irrigation in arid regions. The models consider the chemical processes of precipitation and dissolution, cation exchange and adsorption of boron. These processes are coupled to a variably saturated water flow model water flow and a plant water uptake model that relates relative yield to water and salinity stress. Simulations using this model show that the traditional (Ayers and Westcot, 1985) calculation method for evaluating plant response to soil salinity overestimates the yield loss, especially at high salinity and low leaching fractions. The major effects are related to two factors: 1) Consideration that the plant responds to salinity of the water taken up by the plant and not average rootzone salinity as assumed and 2) Assumption that leaching fraction and crop ET are fixed inputs rather than crop responses to the stress experienced. These results (Suarez, 2010) suggest that with some relatively small losses in potential yield, we can irrigate crops with more saline water than previously considered, without the need for large quantities of leaching water. Modeling simulations also provide guidance for management options when using low quality waters. For example, Goldberg and Suarez (2006) determined using UNSATCHEM simulations that transient use of high B water is feasible and that the optimal leaching management was different for clay vs. sandy soils. Contrary to existing guidelines, for a single season use of high B waters, minimal water applications and leaching gave the lowest soil water B concentrations.

Literature Cited

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

Goldberg, S. and D.L. Suarez. 2006. Prediction of anion adsorption and transport in soil systems using the constant capacitance model. In: Surface Complexation Modeling. J. Luetzenkirchen (ed.). Interface Science and Technology Series. Elsevier. 11:491-517.

Simunek, J., and D.L. Suarez. 1997. UNSATCHEM: Unsaturated water and solute transport with equilibrium and kinetic chemistry. Soil Sci. Soc. Am. J. 61(6):1633-1646.

Suarez, D.L. 2010. Irrigation water quality assessments. In: K.K. Tanji and W.W. Wallender (eds.) ASCE Manual and Reports on Engineering Practice No. 71. Agricultural Salinity Assessment and Management (2nd Edition). ASCE, NY. Chapter 11 (In press).

Suarez, D.L. 2010. Soil salinization and management options for sustainable crop production. In: M. Pessarakli (ed.) Handbook of Plant and Crop Stress. 3rd Edition. CRC Press. Boca Raton, FL. Chapter 3 pp: 41-54.

Suarez, D.L., Rhoades, J.D., Lavado, R. and C.M. Grieve. 1984. Effect of pH on saturated hydraulic conductivity and soil dispersion. Soil Sci. Soc. Am. J. 48(1):50-55.

Suarez, D.L. and P.J. Vaughan. 2001. FAO SWS Manual. George E. Brown Jr. Salinity Laboratory Research No. 147 pp: 1-113.

Suarez, D.L., Wood, J.D. 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., Wood, J.D. and S.M. Lesch. 2008. Infiltration into cropped soils: Effect of rain and sodium adsorption ratio – Impacted irrigation water. J. Environ. Qual. 37:S169-S179.

Research on Soil Quality in California: Processes, Justification and Long-term Benefits

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Introduction

The concept of soil quality encompasses biological, chemical, and physical properties that sustain productivity, protect the environment and support healthy organisms and beneficial components of biodiversity. Soil quality can be defined as 'the capacity of soil to function' (Karlen et al., 1997) and many soil functions result in ecosystem services, i.e., the conditions and processes through which ecosystems, and their species, benefit humans (Daily, 1997). Provision of ecosystem services is at the forefront of many current policy debates related to natural resource management. Conducting agricultural research at the landscape level allows us to assess how management decisions influence soil quality across many soil types, or in adjacent waterways. In this presentation, two recent studies will be described that show approaches for scaling up soil quality research to the landscape level, and evaluating the relationship between soil quality and the biodiversity of plant and soil communities.

Soil Quality in Different Habitats of an Organic Farm

Indicators of soil quality and communities of plant and soil organisms were monitored in six distinct habitats of an organic farm in the Sacramento Valley (Smukler et al., 2010). These included production fields of tomato and oats, riparian corridor, hedgerows, a system of drainage ditches, and tailwater ponds. Riparian and hedgerow habitats with woody vegetation stored 18% of the farm's total carbon (C), despite occupying only 6% of the total area. In the riparian corridor, surface water infiltration rates corridor were >200% higher than in the production fields. The tailwater pond reduced total suspended solid concentrations in irrigation runoff by 97%. The soil emissions of nitrous oxide (N_2O-N) and nitrate (NO_3^--N) leaching were low across the entire farm. Both were slightly higher in the drainage ditches than other habitat types, which were generally similar. Differences between habitats were less pronounced for belowground organisms, i.e., nematode functional groups, microbial communities (based on phospholipid fatty acid (PLFA) analysis) and earthworm taxa, than for plants. Non-production habitats increased biodiversity (particularly plants) and specific soil functions (e.g. water regulation and carbon storage). Extrapolating relative tradeoffs to the area of the entire farm showed that habitat enhancement of riparian corridors and planting hedgerows could substantially increase soil-derived ecosystem services (e.g., carbon storage, infiltration, and nutrient retention) with only minor loss of production area.

Landscape Inventory of Soil Quality in Cropland and Rangeland Waterways

In a 150 km^2 region in the Sacramento Valley, soil quality indicators, plant communities, and belowground biodiversity were inventoried in riparian areas and adjacent agricultural fields (Young-Mathews et al., 2010; Culman et al. 2010). The area was composed approximately equally of irrigated row crops and rangelands. Data were collected on soil physical and chemical properties and plant, nematode and soil microbial communities (PLFA analysis) along 50-m transects at 20 sites. Three samples were taken along the transects: 1-m from the waterway, on the bench above the waterway, and 50-m from the waterway in the adjacent crop field or grazed grassland. These sites were chosen with a geographic information system (GIS) approach that represented the different land use, soil, and vegetation types in the entire landscape. Riparian zones had nearly twice as much total C storage per hectare as the adjacent land managed for agricultural uses. They also had greater plant diversity than agricultural fields, but generally lower soil microbial and nematode diversity and abundance. When woody plant communities were present in the riparian zone, plant diversity and species richness were higher, and soil NO_3^--N and plant-available phosphorus levels were lower, suggesting a positive benefit on reducing nutrient movement into waterways. Greater plant species richness, nematode food web structure, total microbial biomass, woody C storage and lower soil NO_3^--N and phosphorus loading were correlated with higher visual riparian health assessment scores. These results suggest that waterways and riparian habitats can be managed to improve soil quality and to provide multiple ecosystem services. This type of information can provide a basis for policies that support farmers' stewardship of agricultural lands and improve management for multiple ecosystem services, including food and fiber production.

Literature Cited

Culman, S.W., Young-Mathews, A., Hollander, A.D., Ferris, H., Sánchez-Moreno, S., O'Geen, A.T., and Jackson, L.E.. Biodiversity and soil ecosystem functions over a landscape gradient of agricultural intensification in California. Landscape Ecology 25:1333-1348.

Daily, G.C. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington D.C., USA

Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F., Schuman, G.E. 1997. Soil quality, a concept, definition, and framework for evaluation. Soil Sci. Soc. Am. J. 61:4-10.

Smukler, S.M., Jackson, L.E., Moreno, S., Fonte, S.J., Ferris, H., Klonsky, K., O'Geen, A.T., Scow, K.M., and Steenwerth, K.L. 2010. Biodiversity and multiple ecosystem functions in an organic farmscape. Agriculture, Ecosystems and Environment 139:80-97.

Young-Mathews, A., Culman, S.W., Sánchez-Moreno, S., O'Geen, A.T., Ferris, H., Hollander, A.D., and Jackson, L.E. 2010. Plant-soil biodiversity relationships and nutrient retention in agricultural riparian zones of the Sacramento Valley, California. Agroforestry Systems 80:41–60.

New Soil Survey Applications to Investigate California's Soil Resource

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Introduction

Now that hardcopies of soil surveys are no longer in print, digital soil survey products have become the primary mechanism of data delivery. While the National Cooperative Soil Survey has made considerable progress in expanding the delivery of soil survey data via the internet, web-based interfaces to soils information do not lend themselves to field uses, and are not always easily adopted by non-technical users. The California Soil Resource Laboratory at UC Davis has developed an online Soil Survey (SoilWeb) and GPS-enabled smartphone application to support on-demand access to soil survey information anywhere (with cell phone coverage) in the contiguous 48 states. The smartphone application was designed to take advantage of the GPS or cell tower triangulation capabilities of modern smartphones in order to perform location-based queries of soil survey data in the field.

Design

The spatial queries are sent to the UC Davis Soil Resource Laboratory's online interface to soil survey information, http://casoilresource.lawr.ucdavis.edu/soilsurvey. Query results are presented as a series of soil profile sketches, depicting soil horizons, series names, landscape position, and taxonomic classification. Clicking on a soil name links to SoilWeb's Map Unit Summary Page. There are four main pieces of information in the map unit summary page: 1) the map unit composition, 2) cartographic information about the map unit, 3) aggregated data about the soil map unit, and 4) map unit notes. Cartographic information includes map unit name and symbol, and map unit type. The acreage of the selected map unit polygon, and total map unit acreage within the current survey area are presented. Aggregated map unit data include: farmland class, available water storage, flood frequency, drainage class, hydric condition, minimum water table depth, and minimum bedrock depth. These values and interpretations represent dominant conditions associated with the current map unit. Links to adjacent map unit polygons are presented at the bottom of the page for navigation without having to return to the map interface. A static map highlighting the selected map unit polygon is included to the right of the data tables.

The soil components of the queried map unit are summarized at the top of the map unit summary page, sorted by percent composition, with links to associated soil information. Depending on the vintage of the survey area, data may or may not be available for minor components. For more recent soil surveys, attribute data for dominant components and inclusions are available. For older soil surveys, only the dominant soil components are populated with attribute data. In these circumstances a link to *similar* component data (usually from another map unit) is generated for minor components and inclusions– based on component name (usually soil series) and slope class. A disclaimer is therefore added, suggesting that values should be taken as approximations. This feature was designed as a convenience for projects involving older survey data.

The component summary page contains detailed properties and interpretations specific to a single component (soil type) within a map unit. This aspect of SoilWeb separates it from any other web-based soils product available. Soil data are portrayed on this page in a variety of ways conducive to learning about soils. An example soil profile with horizon designations and depths is generated to help users visualize the vertical structure of the selected component. This profile sketch is dynamically created from horizon boundary and designation information, extracted from the current component's horizon data.

The ability of the online soil survey to link to other websites offers a powerful means of delivering information. There are multiple examples of how this is accomplished in the online soil survey. For example the soil order link can be accessed with a click of the mouse taking the user to the University of Idaho's Soil Orders Website. This website defines each soil order, discusses the properties of each, and provides multiple pictures of soils and associated land uses. Deep linking to the USDA PLANTS database, USDA Ecological Site Information System (ESIS), NRCS official series description (OSD), and Soil Series Extent Mapping Tool (SEM Tool) are also provided within each component summary.

Several land classification indices are listed including Storie Index (Storie, 1978) and USDA Land Capability Class (LCC) (Soil Survey Staff, 2007) for irrigated and non-irrigated systems. These interpretations are not always clearly explained, especially in digital data delivery systems. We have linked these topics to the National Soil Survey Handbook (Soil Survey Staff, 2007), which defines each item and the methods involved in generating the interpretation. A complete listing of suitability ratings can be accessed by named links, including interpretations for waste related, engineering, recreational, urban, irrigation, runoff and wildlife. Specific parameters related to erosion (due to wind and water), runoff and drainage class are listed. When available (in recently digitized surveys), parent material and geomorphology are also listed.

Several commonly accessed soil physical and chemical properties are presented in (dynamically generated) graphical format. These depth profile plots are well suited toward visual extraction of important trends, such as subsurface accumulation of clay, salinity and permeability. Clicking on one of the graphs brings up a tabular version of the same data. Each profile graph heading is linked to its definition in the Soil Survey Handbook.

For example we have linked each soil series to the UC Riverside Nitrate Hazard Rating Index (Wu et al., 2005). The linkage of the online soil survey with the nitrate hazard leaching index allows users to easily identify their soils of interest and then directly link to the index to generate a hazard rating. In a similar fashion, a link is provided that exports horizon information to a downloadable CSV (comma separated value) file.

Most people are familiar with and comfortable using, the popular web mapping application Google Maps. Google allows individuals to use the Google Maps API (map controls, base imagery, location search features, etc.) within user-created applications. Map unit polygon overlays switch between SSURGO and STATSGO data sources when the map scale crosses a pre-set threshold of 1:35,000. A legend is dynamically created and displayed using the viewport geometry and SoilWeb map unit look up API. Although lacking many of the features present in the standard SoilWeb map interface, the Google Maps interface provides a very simple approach to exploring Soil Survey in a framework (Google Maps) that is now ubiquitous.

Google's 3D geographic data viewer (Google Earth) and NASA's similar product (World Wind) are both widely known and actively used by a large number of people. Simple controls and availability of high resolution imagery and terrain data make these platforms an ideal environment for exploring soil survey data. From the standard map interface to SoilWeb it is possible to save the contents of the current viewport as a KML file, which can be subsequently opened in either Google Earth or World Wind. Alternatively, the streaming KML interface to SoilWeb (based on the SoilWeb API) can be added to Google Earth as a network link, which is refreshed (updated) when the contents of the view are changed. Map unit polygons from STATSGO are presented at regional scales (i.e. 1:250K to 1:35K), and SSURGO map unit polygons are presented at finer cartographic scales. Map unit polygons are "draped" over the landscape surface, and labeled with map unit symbols. Clicking on a map unit label brings up the corresponding map unit summary page.

Soil-landscape relationships play an important part in the delineation of map units within a soil survey. The Google Earth interface provides an excellent tool for demonstrating this concept by allowing users to "tilt" the viewport, revealing the terrain shape and superimposed map unit polygons. Current aerial imagery along with the wealth of contextual data available in Google Earth (not to mention future soil-related data layers) are additional highlights of this interface to soil survey data.

SoilWeb and the smartphone application was designed for a wide range of users including educators, students, consultants, soil survey staff, agronomists, as well as the general public. The intent was to enable more people to access, and more importantly, apply soil survey information in a manner that best accommodates how soil surveys are used-- *in the field*. Several additional features are currently planned for future releases of the application including a dynamically updated map interface, queries based on user-defined geographic coordinates, and enhanced soil science educational material. The smartphone application is available at no cost for iPhone and Android OS platforms. Details of the application appear in the latest issue of Soil Science Society of America (Beaudette and O'Geen, 2010). Details about the online capabilities of SoilWeb are published in Computers and Geosciences (Beaudette and O'Geen, 2009). Additional information on SoilWeb and the smartphone application can be found at http://casoilresource.lawr.ucdavis.edu/soilsurvey.

Literature Cited

Beaudette and O'Geen, 2010. An iphone application for on demand access to digital soil survey information. Soil Science Society of America Journal. 74:1682-1684.

Beaudette, D., and A.T. O'Geen 2009. Soil-Web: An online soil survey for California, Arizona and Nevada. Computers and Geosciences. 35:2119-2128.

Soil Survey Staff, 2006a. Soil Survey Geographic (SSURGO) Database for Survey Area, State. U.S. Department of Agriculture, Natural Resources Conservation Service [Online] Available: "http://soildatamart.nrcs.usda.gov" [Accessed 05/08/2006].

Soil Survey Staff, 2006b. U.S. General Soil Map (STATSGO) for California. U.S. Department of Agriculture, Natural Resources Conservation Service. [Online] Available http://soildatamart.nrcs.usda.gov [Accessed 05/08/2006].

Soil Survey Staff, 2007. National Soil Survey Handbook , title 430-VI. U.S. Department of Agriculture, Natural Resources Conservation Service. [Online] Available: http://soils.usda.gov/technical/handbook/ [Accessed 05/15/2007].

Storie, R.E., 1978. Storie index soil rating. University of California Division of Agricultural Sciences, Special Publication 3203, Oakland, CA, 4pp.

Understanding the Fate of Antibiotics in Concentrated Animal Feeding Operations

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Introduction

Human population growth and increased urbanization have lead to intensified demands on agricultural production. The need for higher productivity on reduced land areas, in conjunction with the development of new technology and the economic advantage of increased size, have shifted small-scale animal farms to concentrated animal feeding operations (CAFOs), potentially reducing soil and water quality of adjacent areas. CAFOs generate large volumes of animal waste, containing a variety of nutrients and pharmaceuticals, much of which is applied to agricultural fields.

The nontherapeutic use of veterinary antibiotics in animal husbandry operations is under increasing scrutiny as some of the negative effects these compounds can have on environmental and human/animal health are becoming evident. Leaking storage tanks and land application of manure are potential routes for antibiotics to enter the soil and be transported to water supplies via leaching and/or surface runoff. By design, these compounds are antibiological agents and can have deleterious effects on soil and aquatic microbial communities. Transport of antibiotics from animal waste through soil to surface and groundwater threatens watershed habitats, human and livestock drinking water, and agricultural irrigation supplies. With increasing demands for food production, and the common occurrences of CAFOs using antibiotics for nontherapeutic purposes, it is critical that we understand antibiotic transport and the bacterial development of antibiotic resistance (ABR) in the environment.

Literature Review

Antibiotics are used in animal agriculture for both treatment and prevention of disease. The addition of antibiotics to feed at nontherapeutic levels can stimulate growth in agricultural animals (Kummerer, 2003), increasing feed efficiency from 2 to 5% and final body mass between 4 and 8% (Ewing and Cole, 1994). However, most of the antibiotics given to animals are not absorbed and pass through the animal unaltered with the excrement (Boxall et al., 2002), and in some cases up to 90% of the antibiotic is not metabolized (Kumar et al., 2005). Antibiotics are agricultural chemicals of emerging concern due to their potential to alter microbial communities through development of ABR. For example, land application of dairy manure can lead to selection for multidrug resistant enteric bacteria (Burgos et al., 2005). Another study screening several municipal, residential, and agricultural locations found the most antibiotic resistant bacteria (95%) in dairy manure (Esiobu et al., 2002), implicating antibiotic use in dairies as a source for particular concern. These findings are significant because transfer of antibiotic resistant genes to humans and other mammals can reduce our ability to treat infectious disease (Ferber, 2002).

The largest dairy industry in the world is found in California, with over 2000 dairies producing approximately 23% of the U.S. milk supply (Shaw et al., 2007). Not surprisingly, dairy is the largest confined animal industry in California with many dairies having herd size of

1000 animal units. Dairies within the state house approximately 1.8 million lactating cows and 1.5 million dry cows and heifers (Shaw et al., 2007) generating large volumes of solid and liquid manure. A range of antibiotics (i.e., monensin, sulfonamides, tetracyclines and their degradation products, lincomycin) were detected in soil cores (0 to 30 cm) and shallow groundwater under Central Valley dairies and fields receiving manure, indicating transport and persistence of veterinary antibiotics (Watanabe et al., 2010). Currently, the mechanisms of antibiotic transport and retention are not well understood, however facilitated transport with organic matter (OM) or colloidal mineral phases is possible.

Antibiotics typically have high water solubility, are polar, and contain functional groups (e.g., –C=O, $–NO_2$, $–NH_2$, –OH, –CN, –OH, –COOH) which facilitate sorption to charged surfaces (Lee et al., 2007). In soil and groundwater, minerals and humic substances possess variable charge and exert a large influence on the mobility and sequestration of antibiotics. A number of mechanisms are possible for binding of various antibiotics to clay minerals, metal (hydr)oxides and humic substances, including cation exchange, complexation, cation bridging, and hydrogen bonding. Studies investigating antibiotic sorption demonstrate varying sorption with tetracycline compounds binding strongly to soil, macrolids binding less, followed by ionophores, and then sulfonamides (Sassman and Lee, 2005; Tolls, 2001).

One antibiotic currently receiving increased scrutiny is monensin, an ionophoric veterinary antibiotic used commonly in poultry, beef, and dairy industries for increased animal growth and pathogen control (Bagg et al., 2000; Sassman and Lee, 2007). In 2004, monensin was approved as the only antibiotic permitted for lactating cows to increase milk production by the US Food and Drug Administration (U.S. Food and Drug Administration, 2004). Ionophore antibiotics, such as monensin, typically have higher toxicity than other antibiotics. Analysis of its overall toxic profile has lead monensin to be classified as a high priority antibiotic for detailed risk assessment (Capleton et al., 2006). The concentration of monensin in cattle manure can range from 1 to 5 mg L^{-1} (Donoho, 1984) and once in the environment can persist and reach groundwater supplies, as hydrolysis is uncommon and photolysis is slow. However, biodegradation is possible and half lives are reported between less than 2 d (Sassman and Lee, 2007) to 13.5 d (Carlson and Mabury, 2006). Based on sorption coefficients (Sassman and Lee, 2007; Tolls, 2001) monensin is expected to be more mobile in soils than most veterinary antibiotics. Monesin has been detected in river water and sediments near agricultural activities in Colorado (Kim and Carlson, 2006), in surface water adjacent to agriculture in Ontario, Canada (Lissemore et al., 2006), and in groundwater under dairy operations in California (Watanabe et al., 2008).

Other frequently used, and important, classes of antibiotics detected in soil and water samples from areas influenced by dairies in the Central Valley are tetracyclines and sulfonamides. Examples of two common antibiotics in these classes are oxytetracycline and sulfamethazine; concentrations in cattle manure can be as high as 19 mg L^{-1} (30 to 135 days old) and 3.2 mg L^{-1} (calves), respectively (De Liguoro et al., 2003; Haller et al., 2002). Antibiotics in both of these classes are also widely used in humans, and development of ABR could have a direct impact on our ability to economically fight certain bacterial infections. In soil, the sorption of these antibiotics is believed to occur primarily with clay minerals; tetracyclines tend to bind strongly, whereas sulfonamides have lower sorption coefficients (Tolls, 2001) and are expected to be more mobile.

Research is ongoing to evaluate the specific mechanisms for veterinary antibiotic transport and degradation from CAFOs in order to better evaluate the risk for development of antibiotic resistance in bacteria which could be detrimental to human and animal health. Current research has demonstrated that many veterinary antibiotics can be transported go ground- and surface-water and persist in the environment longer that what is predicted based on laboratory degradation studies alone. There is a continuing need for research which addresses transport and transformation pathways for veterinary antibiotics from CAFOs to develop predictive models and guidelines for storage and land application of dairy manures to agricultural lands at the field- and farm-scale.

Literature Cited

Bagg, R., G. Vessie, J. Wilson, and P. Dick. 2000. Comparison of the effects of monensin and decoquinate on feed intake and growth performance in dairy calves up to weaning age. Canadian Journal of Animal Science. 80:721-723.

Boxall, A.B.A., P. Blackwell, R. Cavallo, P. Kay, and J. Tolls. 2002. The sorption and transport of a sulphonamide antibiotic in soil systems. Toxicology Letters. 131:19-28.

Burgos, J.M., B.A. Ellington, and M.F. Varela. 2005. Presence of multidrug-resistant enteric bacteria in dairy farm topsoil. Journal of Dairy Science. 88:1391-1398.

Capleton, A.C., C. Courage, P. Rumsby, P. Holmes, E. Stutt, A.B.A. Boxall, and L.S. Levy. 2006. Prioritising veterinary medicines according to their potential indirect human exposure and toxicity profile. Toxicology Letters. 163:213-223.

Carlson, J.C., and S.A. Mabury. 2006. Dissipation kinetics and mobility of chlortetracycline, tylosin, and monensin in an agricultural soil in Northumberland County, Ontario, Canada. Environmental Toxicology and Chemistry. 25:1-10.

De Liguoro, M., V. Cibin, F. Capolongo, B. Halling-Sorensen, and C. Montesissa. 2003. Use of oxytetracycline and tylosin in intensive calf farming: evaluation of transfer to manure and soil. Chemosphere. 52:203-212.

Donoho, A.L. 1984. Biochemical-studies on the fate of monensin in animals and in the environment

Journal of Animal Science. 58:1528-1539.

Esiobu, N., L. Armenta, and J. Ike. 2002. Antibiotic resistance in soil and water environments. International Journal of Environmental Health Research. 12:133-144.

Ewing, W.N., and D.J.A. Cole. 1994. The living gut. An introduction to microorganisms in nutrition Context, Dungannon, Ireland.

Ferber, D. 2002. Antibiotic resistance - Livestock feed ban preserves drugs' power. Science. 295:27-28.

Haller, M.Y., S.R. Muller, C.S. McArdell, A.C. Alder, and M.J.F. Suter. 2002. Quantification of veterinary antibiotics (sulfonamides and trimethoprim) in animal manure by liquid chromatography-mass spectrometry. Journal of Chromatography A. 952:PII S0021-9673(02)00083-3.

Harter, T., H. Davis, M.C. Mathews, and R.D. Meyer. 2002. Shallow groundwater quality on dairy farms with irrigated forage crops. J. Contam. Hydrol. 55:287-315.

Kim, S.C., and K. Carlson. 2006. Occurrence of ionophore antibiotics in water and sediments of a mixed-landscape watershed. Water Research. 40:2549-2560.

Kumar, K., S.C. Gupta, Y. Chander, and A.K. Singh. 2005. Antibiotic use in agriculture and its impact on the terrestrial environment, p. 1-54 Advances in Agronomy, Vol. 87.

Kummerer, K. 2003. Significance of antibiotics in the environment. Journal of Antimicrobial Chemotherapy. 52:5-7.
Lee, L.S., N. Carmosini, S.A. Sassman, H.M. Dion, and M.S. Sepulveda. 2007. Agricultural contributions of antimicrobials and hormones on soil and water quality. Advances in Agronomy. 93:1-68.
Lissemore, L., C.Y. Hao, P. Yang, P.K. Sibley, S. Mabury, and K.R. Solomon. 2006. An exposure assessment for selected pharmaceuticals within a watershed in southern Ontario. Chemosphere. 64:717-729.
Sassman, S.A., and L.S. Lee. 2005. Sorption of three tetracyclines by several soils: Assessing the role of pH and cation exchange. Environ. Sci. Technol. 39:7452-7459.
Sassman, S.A., and L.S. Lee. 2007. Sorption and degradation in soils of veterinary ionophore antibiotics: monensin and lasalocid. Environmental Toxicology and Chemistry. 26:1614-1621.
Shaw, S.L., F.M. Mitloehner, W. Jackson, E.J. Depeters, J.G. Fadel, P.H. Robinson, R. Holzinger, and A.H. Goldstein. 2007. Volatile organic compound emissions from dairy cows and their waste as measured by proton-transfer-reaction mass spectrometry. Environ. Sci. Technol. 41:1310-1316.
Tolls, J. 2001. Sorption of veterinary pharmaceuticals in soils: A review. Environ. Sci. Technol. 35:3397-3406.
U.S. Food and Drug Administration. 2004. FDA Approves Rumensin® for incresaed milk production efficiciency in dairy cows. Center for Veterinary Medicine, Department of Health and Human Services, Rockville, MD.
Watanabe, N., T.H. Harter, and B.A. Bergamaschi. 2008. Environmental Occurence and Shallow Ground Water Detection of the Antibiotic Monensin from Dairy Farms. Journal of Environmental Quality. 37:S75-S78.
Watanabe, N., B.A. Bergamaschi, K.A. Loftin, M.T. Meyer, and T. Harter. 2010. Use and Environmental Occurrence of Antibiotics in Freestall Dairy Farms with Manured Forage Fields. Environ. Sci. Technol. 44:6591-6600.

American Society of Agronomy
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Session III
Water Management

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Evapotranspiration of Fully-irrigated Alfalfa in Commercial Fields

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Introduction

Alfalfa is California's single largest agricultural water user due to the amount grown, typically about 1 million acres, and its long growing season. Seasonal alfalfa water applications generally range from 4,000,000 to 5,500,000 acre-feet.

Seasonal alfalfa evapotranspiration (ET) or crop water use values commonly used in California range from 48 to 49 inches in the Sacramento and San Joaquin Valleys, 76 inches in the Imperial Valley, and 33 inches in the Intermountain Region of northern California. However, sources of these values are not clear. Most likely, they were calculated in the 1960 or 1970's as the product of a reference crop ET and crop coefficients. The crop coefficients appear to have been developed at UC Davis (Doorenbos and Pruitt, 1977), but no publications appear to exist on this research.

The California Department of Water Resources funded a project with the initial objective of determining the potential of deficit irrigation of alfalfa as a strategy for transferring water from water-rich areas to water-poor areas. As part of this project, the ET of fully irrigated alfalfa was also determined at various locations throughout California.

Methods and Materials

Alfalfa ET was determined in commercial fields using eddy covariance and surface renewal energy balance methods. These are micrometeorological techniques that use data on net radiation, air temperature, humidity, wind speed, soil temperature, soil heat flux, and soil water content for calculating ET. Twenty four data sets of seasonal alfalfa ET were collected. The alfalfa ET data were compared with the California Irrigation Management Information System (CIMIS) reference crop ET.

Sites were selected in the Imperial Valley, southern San Joaquin Valley (Kern County), Sacramento Valley (Yolo County), Scott Valley (near Yreka), and Tulelake (Klamath Basin). Site specific characteristics are in Table 1. Measurements were made during the calendar year for the Sacramento, San Joaquin, and Imperial valleys because of the 12-month growing season at these locations. A crop season of mid-March to the end of September was assumed for the Intermountain Region sites, where the last harvest generally occurred by the end of September.

Table 1. Site-specific characteristics..

Region	Site	Elevation (ft)	Dominant soil types	Irrigation method
Imperial Valley	LM1	-6	Holtville silty clay	Flood
	LM2	-6	Imperial-Glenbar silty clay loam	Flood
	GZ	36	Imperial-Glenbar silty clay loam	Flood
	EL	-43	Imperial-Glenbar silty clay loam	Furrow
	WA	-240	Glenbar clay loam	Flood
San Joaquin Valley	BU	180	Buttonwillow clay	Flood
Sacramento Valley	CH1	50	Meyers clay; San Ysidro loam	Flood
	CH2	50	Capay silty clay; Myers clay;	Flood
	EE	37	Corval loam	Flood
	EW	54	Sycamore silty clay	Flood
Scott Valley	EN	2,700	Settlemeyer loam	Wheel-line
	AR	2,730	Settlemeyer loam	Center pivot
	FI	2,722	Stoner gravelly sandy loam	Center pivot
	FA	2,673	Diyou loam	Center pivot
Shasta Valley	SH	2,624	Louie loam	Center pivot
Tulelake	TU	4,000	Tulebasin mucky silty clay loam	Wheel-line

Soil water tension was measured using Watermark sensors installed at six-inch depth intervals down to 36 or 48 inches, depending on the site. The sensors were connected to a Monitor data logger with measurements made at 30 to 60 minute intervals, depending on the site.
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Results

Daily ET increased over time reaching maximum values between mid-June to mid-July followed by decreasing daily ET over time (Fig. 1). Superimposed over this trend were decreases in ET during the cutting period and rapid increases in ET after cutting with ET reaching maximum values just before the next cutting for each cutting cycle.

At the Imperial Valley sites, ET behavior between cuttings differed from that found at the other sites. During the mid to late summer, daily ET at the Imperial Valley 2007 and 2008 sites, ET initially increased due to the first irrigation after cutting, but then decreased over time until the next cutting (Fig. 1C). ET values were smaller than reference crop ET during this period. This behavior appears to reflect water logging or “scalding” of alfalfa experienced by flood irrigators on heavy soils during the period of extremely hot temperatures. At the Imperial Valley

2009 and 2010 (GR) sites, starting about DOY 200, (day of year) ET decreased over time to values much smaller than the reference ET until about DOY260. This behavior appeared to be caused by no irrigations during the period of hot temperatures. ET then increased to values equal to the reference ET once irrigation was resumed.
Table 2 shows the measured seasonal ET values and the historical values commonly used for each region. Seasonal ET values of the Imperial Valley (55.6 to 65.1 inches) were smaller than the historical value, while seasonal ET of the San Joaquin Valley (56.6 to 59.8 inches) and the Sacramento Valley (50.4 to 55.0 inches) were larger than the historical values. Seasonal ET of the Intermountain Region ranged from 29.6 to 38.7 inches, larger than the historical value. The small value of 29.6 inches (EN 2008) was caused by smoke from forest fires in Scott Valley while the value of 33.2 inches (EN 2009) was the result of inadequate irrigation water management.

Crop coefficients were minimal during the harvest period and maximum just before the next harvest during the part of the crop season where harvests occurred except for the high temperature period of the Imperial Valley (Fig 2). Prior to and after the harvest period crop coefficients varied considerably over time, reflecting the variability in both ET and reference ET during those periods. However, using real time crop coefficients is not practical for growers to estimate alfalfa ET because of the variability during a harvest cycle. Thus, seasonal average coefficients are recommended (Table 2). Most of the seasonal crop coefficients were between 0.9 and 1.0. Average values were 0.91 for the Imperial Valley, 1.01 for the southern San Joaquin Valley, 0.94 for the Sacramento Valley, and 0.95 for the Intermountain Region. The average value recommended by Doorenbos and Pruitt (1977) is 0.95.

Conclusions

Seasonal ET values determined from climate and soil data collected in commercial fields differed from the historical ET generally used for alfalfa in California. Seasonal values for the Imperial Valley were smaller than the historical value, but they were larger than the historical ET for the Sacramento/San Joaquin Valley and the Intermountain Regions. Average crop coefficients determined for the commercial field data were similar to the historical recommended values.

Literature Cited

Doorenbos, J. and W.O. Pruitt. 1977. Crop Water Equipments: guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper 24, Food and Agriculture Organization of the United Nations.

Hargreaves, G.L., G.H. Hargreaves, J.P. Riley. 1985. Irrigation water requirements for the Senegal river basin. Journal of Irrigation and Drainage Engineering 111(3): 265-275.

Table 2. Measured seasonal ET for each site/year, reference ET, regional historical ET, and average crop coefficients. For all sites except the Intermountain Region, the crop season is 12 months. A crop season of mid-March to the end of September was used for the Intermountain Region. The California Irrigation Management Information System (CIMIS) reference ET was used for all sites except Scott and Shasta Valleys, where the Hargreaves equation (Hargreaves et al., 1985) was used to determine reference ET. No CIMIS stations exist in those valleys.

Region	Site	Year	Seasonal ET (inches)	Seasonal Reference ET (inches)	Historical ET (inches)	Average crop coefficients
Imperial Valley	LM1	2007	57.4	73.2	76	0.82
	LM2	2008	65.1	73.3		0.91
	LM2	2009	55.6	67.9		0.94
	GZ	2010	60.5[1]	67.5[1]		0.96[1]
	EL	2010	55.3[1]	64.6[1]		0.91[1]
	WA	2010	61.4[1]	64.6[1]		0.98[1]
San Joaquin Valley	BU	2007	56.6	57.0	49	1.01
	BU	2008	59.4	59.3		1.01
Sacramento Valley	CH1	2005	50.4	63.6	48	0.92
	CH2	2006	54.4	55.9		0.93
	CH2	2007	55.0	58.0		1.04
	CH2	2008	50.4	59.4		0.88
	EE	2010	44.3[2]	41.8[2]		0.98[2]
	EW	2010	39.5[3]	45.7[3]		0.89[2]
Scott Valley/Shasta Valley	EN	2007	38.3	44.0	33	0.90
	EN	2008	29.4	42.6		0.69
	EN	2009	33.2	40.4		0.85
	AR	2010	36.1	37.4		0.99
	FI	2009	38.8	40.4		0.99
	FI	2010	37.3	37.4		0.98
	FA	2010	34.7	37.4		0.90
	SH	2009	38.8	41.1		0.90
Tulelake	TU	2007	39.0	40.5	33	0.99
	TU	2008	34.3	36.5		0.96

[1] As of Nov. 3, 2010; [2] As of Nov 2, 2010; [3] As of Oct 21, 2010

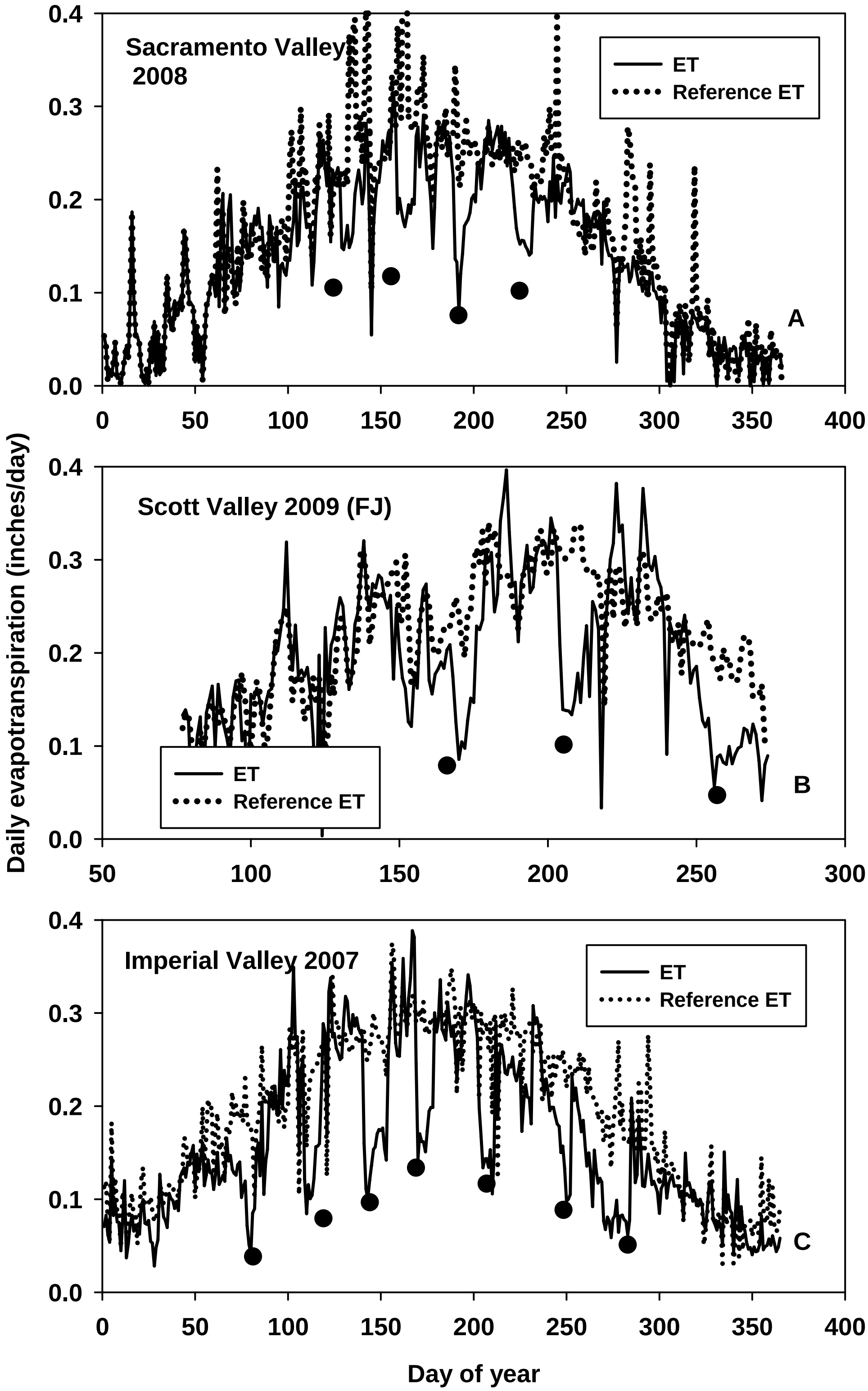

Figure 1. Daily alfalfa and reference evapotranspiration for (A) Sacramento Valley 2008, (B) Scott Valley 2009 (FJ), and (C) Imperial Valley 2007. The black dots are the harvest days.

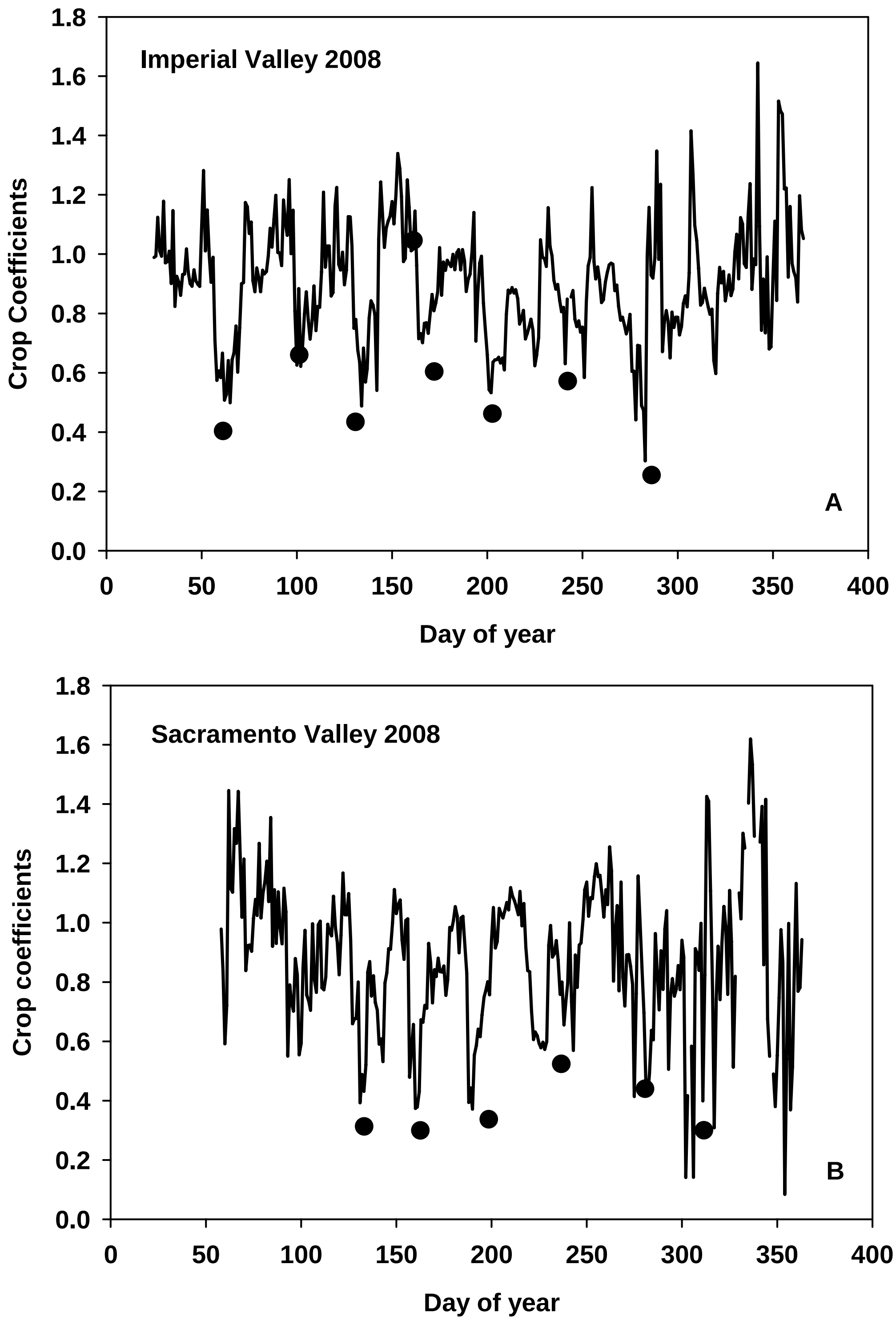

Figure 2.Daily crop coefficients of alfalfa for (A) Imperial Valley 2008, and (B) Sacramento Valley 2008.

Mid-summer Deficit Irrigation of Alfalfa in Commercial Fields

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Introduction

Alfalfa is California's single largest agricultural water user due to the amount grown, typically about 1,000,000 acres, and its long growing season. Because of this water use, interest exists in mid-summer deficit irrigation of alfalfa as a strategy for providing water for water-poor areas particularly during periods of drought. The DWR program proposes transferring an amount of water equal to the difference between the evapotranspiration (ET) of fully-irrigated alfalfa during the period of deficit irrigation and the ET of the deficit-irrigated alfalfa. This midsummer deficit irrigation strategy maintains the relatively high yields of the first part of the year and eliminates irrigations during the summer when yields are small.

Studies have shown that no irrigation during the midsummer reduced the alfalfa yield, but some plant growth occurred in spite of the lack of irrigation, and thus, some level of evapotranspiration occurred. No information exists on differences in midsummer evapotranspiration amounts between fully-and deficit-irrigated alfalfa. Thus, the effect of mid-summer deficit irrigation on ET and yield was studied.

Methods and Materials

Evapotranspiration measurements of fully-and deficit-irrigated alfalfa were made from 2005 to 2008 in the Sacramento Valley and in 2007 and 2008 in the Imperial Valley, southern part of the San Joaquin Valley (Kern County), Scott Valley and Tulelake of the Intermountain Region of northern California. Measurements were made in commercial fields except at the Tulelake site where fields of the University of California Intermountain Research and Extension

Center were used. Flood or border irrigation was used at the Imperial Valley, San Joaquin Valley, and Sacramento Valley sites. Sprinkle irrigation was used at the Scott Valley and Tulelake sites. Site characteristics are listed in the previous paper on ET of fully irrigated alfalfa. Alfalfa ET was determined with eddy covariance and surface renewal energy balance methods.

The fully-irrigated alfalfa was irrigated according to the irrigator's normal practices. The deficit irrigation treatments generally consisted of no irrigation in July, August, and September except at the San Joaquin Valley site, where only one month of deficit irrigation occurred due to the grower's preference. Most of the field was fully-irrigated with a smaller part dedicated to deficit irrigation, the size of which depended on the grower. However, all deficit sites were large enough to satisfy the fetch requirements recommended for methods used to determine ET. Table 1 lists the dates of the start and end of deficit irrigation.

The field scale approach was used to obtain the field-wide conditions experienced by commercial agriculture. A randomized replicated experimental design was not feasible in these commercial fields because of the fetch requirement of about 600 feet of crop around the instruments, the grower's reluctance to dedicate a large area for the deficit irrigation treatments, and the difficulty in irrigating a randomized, replicated experimental design in a commercial field.

Table 1. Dates of the last irrigation before that start of the deficit irrigation period and the next irrigation (end of the deficit period). The deficit irrigation period started after the next harvest following the date of the last irrigation. Numbers in parentheses are day of year.

Site	Date of last irrigation before the deficit irrigation period	Date of next irrigation
Sacramento Valley 2005	July 12 (193)	September 20 (263)
Sacramento Valley 2006	June 18 (169)	September 12 (255)
Imperial Valley 2007	June 27 (178)	October 14 (287)
San Joaquin Valley 2007	July 15 (196)	September 5 (248)
Sacramento Valley 2007	June 8 (159)	No more irrigations in 2007
Scott Valley 2007	June 19 (170)	No more irrigations in 2007
Tulelake 2007	May 8 (128)	No more irrigations in 2007
Imperial Valley 2008	July 3 (185	October 11 (285)
San Joaquin Valley 2008	June 13 (165)	July 27 (209)
Sacramento Valley 2008	June 16 (168)	No more irrigations in 2008
Scott Valley 2008	June 3 (155)	No more irrigations in 2008
Tulelake 2008	June 3 (155)	No more irrigations in 2008

Results

Mid-summer deficit irrigation reduced the ET (Fig. 1), but the amount of reduction was site-specific (Table 2). At the 2007 Imperial Valley site, the alfalfa in the deficit-irrigated site was not harvested, but was allowed to become seed alfalfa, The small ET difference at that site reflected the ET of seed alfalfa during the period of deficit irrigation. Small ET differences occurred at the San Joaquin Valley site due to only 1 to 1.5 months of deficit irrigation and a high soil moisture storage capacity of that soil. Very small ET differences were found at the Tulelake site due to ground water contributing to ET even though in 2008, deficit irrigation occurred during most of the crop season at that site. The smaller 2008 value at the Sacramento Valley site reflects substantial regrowth of alfalfa under deficit irrigation compared to the earlier years, reasons for which are not clear. However, the ET of fully-irrigated alfalfa during the period of deficit irrigation was fairly consistent between sites and years except for the San Joaquin Valley site and the 2008 Tulelake site (due to the relatively longer period of deficit irrigation.

Alfalfa yields were reduced by deficit irrigation, but the amount of reduction was site specific (Table 3). At most sites, some regrowth occurred during the period of deficit irrigation, but the yields per cutting during this period were generally smaller than 0.5 tons per acres, considered to be uneconomical to harvest. At the 2008 Imperial Valley site, the alfalfa went into dormancy during deficit irrigation. At all sites, yield recovered once irrigation was resumed.

Soil moisture tension was small just after an irrigation and increased over time before the next irrigation (data not shown). The amount of increase depended of the frequency of irrigation between harvests. Once deficit irrigation started, soil moisture tension increased to values exceeding 200 centibars (maximum reading of the data loggers).

Table 2. ET differences and ET of fully-irrigated alfalfa during the period of mid-summer deficit irrigation.

Site	Site	Year	ET difference during period of deficit irrigation (inches)	ET of fully-irrigated alfalfa during period of deficit irrigation (inches)
Imperial Valley	LM1	2007	1.2[1]	22.5
	LM2	2008	7.6[3]	18.9
San Joaquin Valley	BU	2006	1.8[2]	8.9[2]
	BU	2007	1.7[2]	14.0[2]
	BU	2008	1.3[2]	6.5[2]
Sacramento Valley	CH1	2005	9.0	17.6
	CH2	2006	7.4	21.2
	CH2	2007	7.8	22.5
	CH2	2008	2.6[3]	18.9
Scott Valley	EN	2007	2.2	20.7
	EN	2008	2.2	21.7
Tulelake	TU	2007	0.2[4]	18.6
	TU	2008	0.6[4]	30.3

[1] Alfalfa went to seed
[2] Only 1 to 1.5 months of deficit irrigation
[3] Substantial growth during the period of deficit irrigation compared to the other years
[4] Shallow ground water contributed to alfalfa ET during period of deficit irrigation

Table 3. Cumulative yield reductions in tons per acre.

Site	Year	Cumulative yield reduction (tons/ac)
Imperial Valley	2007 2008	1.66 *
San Joaquin Valley	2006 2007 2008	0.66 0.85 0.99
Sacramento Valley	2006 2007 2008	2.78 3.73 0.98
Scott Valley	2007 2008	0.83 1.76
Tulelake	2007 2008	0.40 0.78

* Yield was not available

Conclusions

● Both alfalfa ET and yield are reduced by mid-summer deficit irrigation.

● The amount of reduction is not possible to predict because of site specific behavior.

● Alfalfa regrowth can occur during mid-summer deficit irrigation, but anecdotal evidence indicates that this regrowth is uneconomical to harvest.

● The amount of water saved for transfer elsewhere should be based on the ET of fully-irrigated alfalfa during the period of deficit irrigation. The fully-irrigated ET was relatively consistent between sites and years, and can be easily predicted using crop coefficients and reference crop ET.

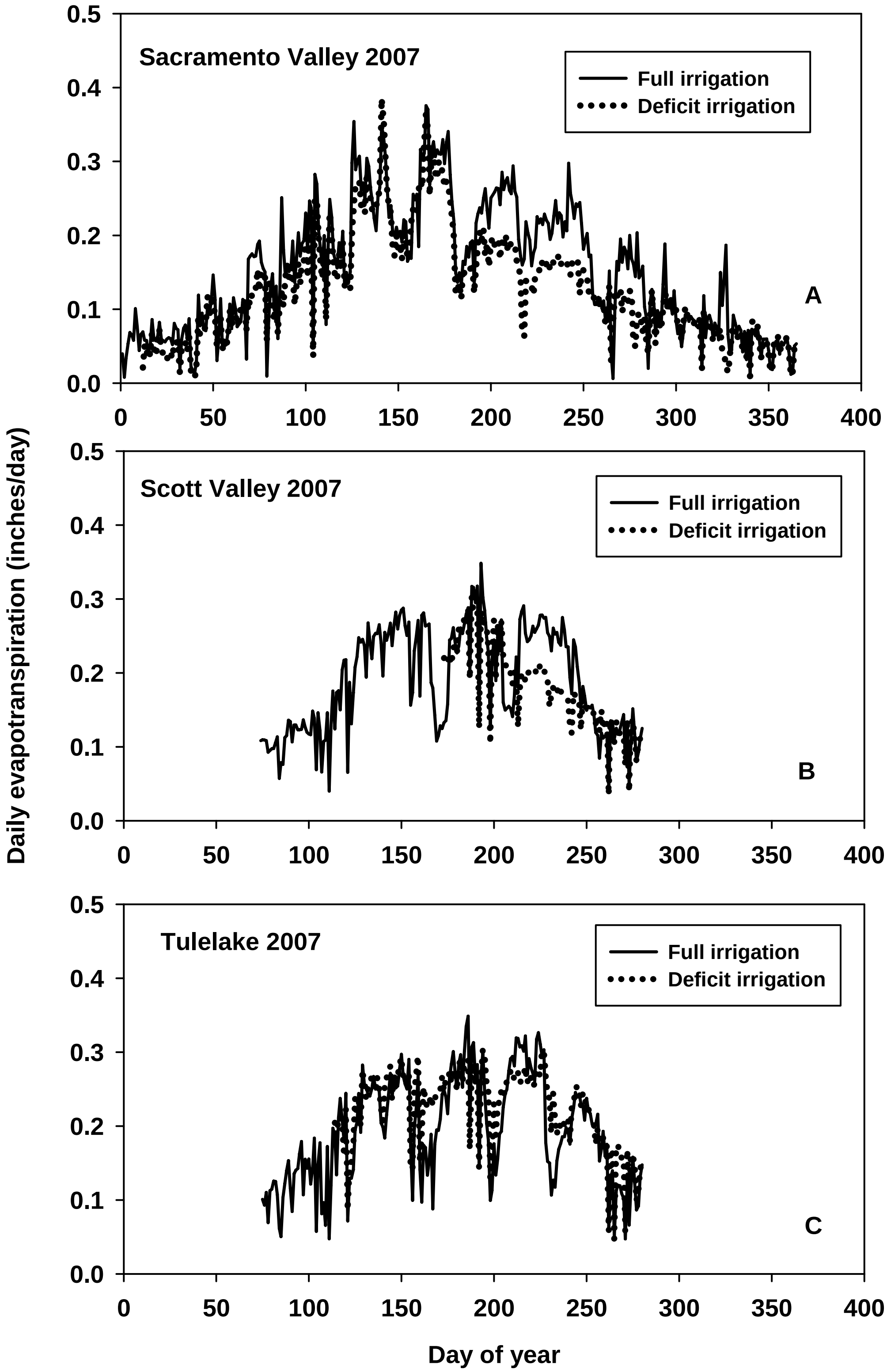

Figure 1. Daily ET of fully-irrigated and deficit-irrigated alfalfa for (A) Sacramento Valley 2007, (B) Imperial Valley 2008, and (C) Scott Valley 2007.

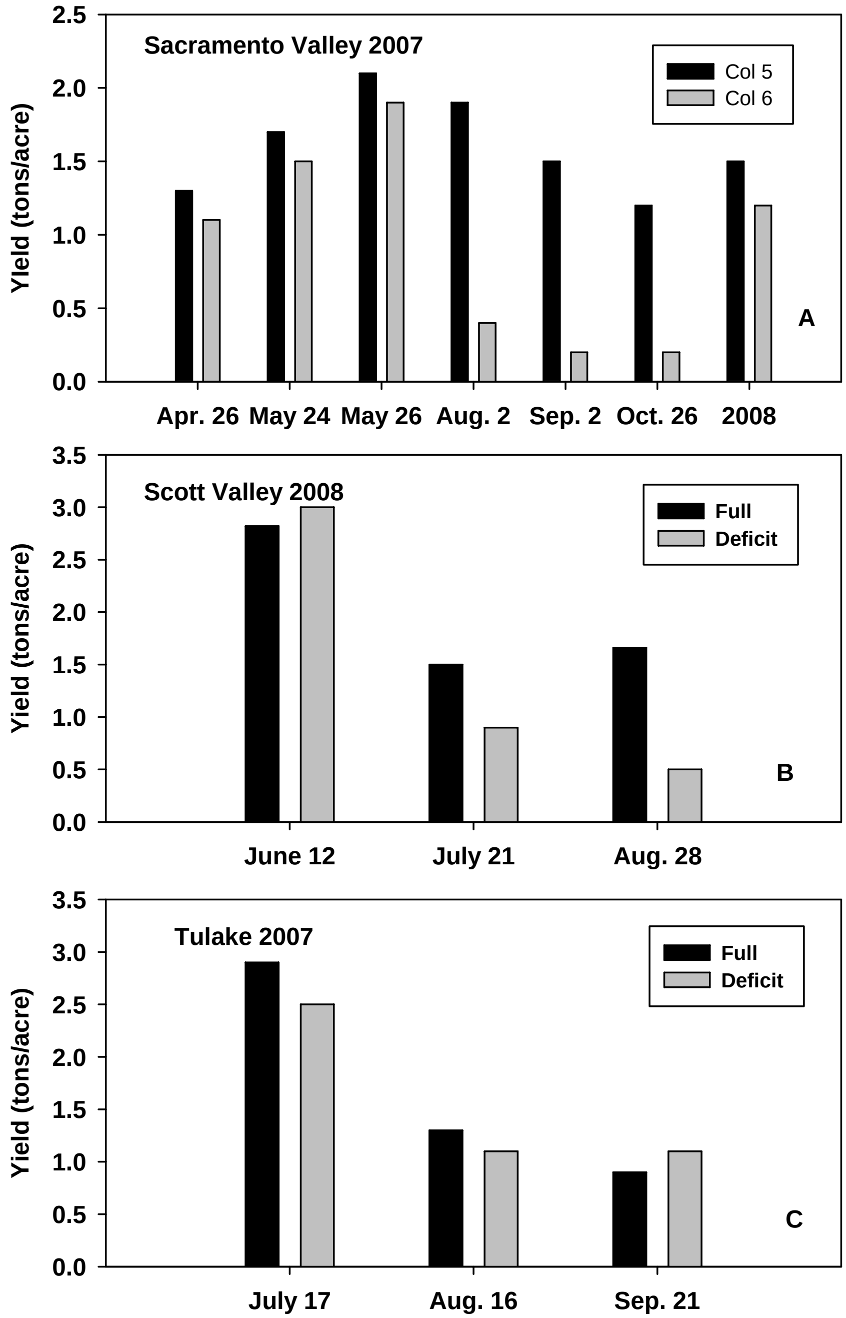

Figure 2. Alfalfa yield per harvest for fully-irrigated and deficit-irrigated alfalfa for (A) Sacramento Valley 2007, (B) Scott Valley 2008, and (C) Tulelake

Irrigation Management Strategies:
San Joaquin Valley Sorghum for Silage

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Introduction

Irrigation water costs and supply limitations are major considerations in cropping decisions in the arid, irrigated western crop production areas. The mix of crops grown in California's San Joaquin Valley includes many moderate to high water use horticultural crops and perennial forage crops along with crops recognized as potentially lower in total water requirement for economic yields. Crops for human food, fiber and animal feed all currently have prominent places in San Joaquin Valley agriculture and many are expected to continue to be competitive in the future. It has become evident during current drought and water restriction situations, however, that growers need information on a mix of crop options that can deliver economic returns with a range of water applications (ie. some acreage of crops with lower water requirements could help balance out higher water use crops). As part of a diversified grower strategy, forage sorghum could have an important role in water-short irrigated production areas if suitable varieties and production strategies can be identified that deliver a cost-effective option for reduced irrigation water needs relative to other forage crop options.

Materials and Methods

Sorghum was grown in trials planted at the College of Sequoias Farm near Tulare, CA. The soil at the site was Tagus loam soil with about 1.7 inches of available water per foot of soil in the upper 3 feet of the soil profile and an average of about 1.45 inches of available water per foot in the 3 to 8 foot depth in the profile. Two sorghum varieties were planted in field trials done in 2009 and 2010, a silage type (variety "FS520", designated as variety "A") and a variety typically grown for grain ("GS900, designated as variety "B"). Both varieties were planted and harvested at the same time (Table 1), with the harvests occurring 102 days after planting (DAP) in 2009 and 108 DAP in 2010. Irrigation plot lengths were approximately 125 feet by 16 beds in width, with 30 inch rows. Irrigation water was applied with gated pipe, one gate per row, with water flow at plot ends blocked using a border ridge. Plots were irrigated individually to allow for separate irrigation application calculations. Both varieties were planted within each irrigation plot replication, for a variety split within each plot. Four different irrigation treatments were established (Table 2), with treatment T1 designed to apply irrigation in amounts to meet estimated full crop evapotranspiration (ETc), and T2 and T3 treatments each eliminating one within-season irrigation, albeit at different timings. A check treatment (T0) did not receive any irrigation after the initial pre-plant irrigation. Plots were harvested on the dates shown (Table 1) when the grain sorghum type variety (GS900) was at soft dough stage using a commercial-type 8-row silage chopper, with silage from each plot collected in a truck that was weighed on a truck scale. Each year the silage type variety (FS520) was less mature than GS900 at harvest, typically in late milk stage of panicle/grain development. Subsamples were taken for evaluation of moisture percent at harvest. Gravimetric soil samples taken close to planting and harvest times were used to determine change in soil water content and to estimate total crop use of soil water, with an assumption that there was no leaching below the 8 foot sampling depth.

Table 1. Planting dates, pre-plant irrigation estimated amounts, and irrigation treatments in 2009 and 2010 silage sorghum studies near Tulare, CA.

Year	Date of Planting	Average pre-plant irrigation (inches)	Average Plant Population (1000's/ac)		Nitrogen application (lbs N/ac)	Rainfall between planting and harvest (inches)	Harvest Date for silage
			Variety A	Variety B			
2009	June 26	6.9	63	48	110	0.0	Oct. 6
2010	Aug. 5	7.7	58	39	110	1.8	Nov. 20

Table 2. Irrigation dates (dates and days after planting (DAP) and amounts for 2009 and 2010.

Irrigation treatment	2009 Irrigation Dates and Amounts (inches (mm) water)				2010 Irrigation Dates and Amounts (inches (mm) water)			
	7/29	8/18	9/10	Total	9/02	9/24	10/18	Total
	34 DAP	54 DAP	77 DAP		29 DAP	51 DAP	75 DAP	
T1	5.7 (145)	4.7 (119)	4.9 (124)	15.3 (389)	5.1 (130)	4.5 (114)	3.9 (99)	13.5 (343)
T2	5.7 (145)	4.6 (117)	-	10.3 (262)	5.1 (130)	4.4 (112)	-	9.5 (241)
T3	-	5.2 (132)	5.3 (135)	10.5 (267)	-	4.8 (122)	4.6 (117)	9.4 (239)
T0	-	-	-	0	-	-	-	0

Results and Discussion

Planting dates were quite different between the two study years, shifting the production period later into the year in 2010. The 2010 production year was also cooler than during the same periods in 2009. The difference in planting date and years resulted in significant differences in heat units calculated at a base of 60 degrees F (see Table 3). Even though the number of days between planting and harvest was longer in 2010 (108 days) than in 2009 (102 days), heat units were much higher, plants were larger and accumulated more dry matter (data not shown) and crop evapotranspiration was higher in 2009 (Table 4).

Table 3. Degree days (base 60 degrees F) determined for 2009 and 2010 study periods as a function of days after planting (DAP). For comparison, degree days base 60F from a CIMIS station site approximately 18 miles from the study site are also shown.

Year of Study	Location and Type of weather station	Degree Days (heat units – single triangle method, base 60 degrees F)			
		Days After Planting (DAP)			
		30	60	90	At harvest (102 DAP – 2009); (108 DAP – 2010
2009	Porterville CIMIS	597	1131	1624	1753
	Portable – at site	558	1090	1510	1645
2010	Porterville CIMIS	511	904	1096	1151
	Portable – at site	480	862	1110	1234

Table 4. Applied water, calculated soil water use, precipitation and crop evapotranspiration (ETc) as a function of irrigation treatment and year.

Year	Irrigation Treatment	Potential Evapo-transpiration Inches (mm)	Total Applied Water		Change soil water stored upper 8 feet of profile (planting vs. harvest time)		Rain during growing season		Crop ETc (applied + soil water use + rain)	
			inches	mm	inches	Mm	inches	Mm	inches	Mm
2009	T1	24.27	15.3	389	3.39	86	0	0	18.69	475
	T2		10.3	262	5.26	134	0	0	15.56	395
	T3		10.5	267	3.73	95	0	0	14.23	362
	T0		-	-	9.12	232	0	0	9.12	232
2010	T1	18.63	13.5	343	1.2	30	1.4	36	16.1	409
	T2		9.5	241	3.44	86	1.4	66	14.34	364
	T3		9.4	239	1.9	48	1.4	36	12.7	323
	T0		-	-	9.92	252	1.4	36	11.32	288

Crop Water Use, Evapotranspiration. Total crop water use shown as Crop ETc in Table 4 reflects differences in degree days and potential evapotranspiration between the two years. In every irrigation treatment with the exception of the unirrigated plants (T0), plants extracted more soil water from the 8 foot soil profile in 2009 than in 2010. The range in estimated crop ETc between the highest irrigation treatment and unirrigated plants was much greater in 2009 (18.69 versus 9.12 inches) than in 2010 (16.1 versus 11.32 inches). These differences in soil water use and ETc reflect both the lack of rain during the growing season in 2009 and the higher level of plant water stress imposed by irrigation delays imposed in treatments T2, T3 in 2009.

Silage Yield Responses. Under the conditions at this test site, the most apparent differences in yield were between years rather than varieties or irrigation treatment. Lower accumulated degree days, prevailing temperatures and ETc in 2010 at the later planting date were reflected in lower average yields in all treatments with the exception of one variety in the T0 treatment. The silage (A, FS-520) and grain-type (B, GS900) varieties responded similarly in terms of yield responses to irrigation treatments within a year. Under study conditions, yield reductions with the T2 and T3 treatments were not significantly different from the T1 treatment even though they had one less irrigation. This reflects both good stored soil water status (from winter rain and pre-plant irrigation) and relatively deep root development at the study site. While the nonirrigated treatment produced large yield reductions both years relative to all irrigated treatments, the ability of these varieties to produce at this level utilizing stored soil water could be helpful in balancing irrigation water decisions in water-short years. It is important to note that the silage yield per unit ETc shown in Table 5 is based on calculated ETc, including soil water use.

Table 5. Silage moisture content at harvest time, silage yields corrected to 70% moisture content as a function of year, variety (A or B) and irrigation treatment.

Year	Irrigation Treatment	Average Moisture Content of Silage at Harvest (percent)		Silage Yield (Tons/ acre) corrected to 70% moisture content		Crop Evapo-transpiration (ETc) Estimate (inches) – from Table 4	Silage Yield per unit Crop ETc (Tons/acre per inch water)	
		Var A	Var B	Var A	Var B		Variety A	Variety B
2009	T1	71	67	27.7	24.4	18.69	1.48	1.31
	T2	69	69	24.4	22.2	15.56	1.57	1.43
	T3	68	69	25.6	22.1	14.23	1.80	1.55
	T0	66	65	13.6	14.5	9.12	1.49	1.59
2010	T1	77	78	17.7	15.4	16.1	1.10	0.96
	T2	78	78	17.6	16.3	14.34	1.23	1.14
	T3	77	77	19.0	16.7	12.7	1.50	1.31
	T0	73	74	14.9	9.6	11.32	1.32	0.85

Irrigation Management of Almonds When Water Supplies are Limited

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Introduction

Many growers are currently faced with proposed cutbacks from water districts, and, depending on the weather, these cutbacks could be increased further. Recent studies of weather patterns for the state have also shown that above-average rainfall has occurred over the last 20-30 years, so that even a return to normal rainfall may pose a problem of water availability to many almond growers and water districts. In the event of a severe drought, when the emphasis may be on tree survival rather than on nut production, growers will need information on what options are available in order to plan their strategy. It may be more profitable for instance, to dehorn certain blocks and not apply irrigation to those, in order to save water so that the remaining blocks can be irrigated normally. Proebsting and Middleton (1980) showed a 100% survival rate of dehorned peach trees in WA, compared to some tree death, in a year with 3.4" of rainfall. Goldhamer (1995) evaluated a 16" in-season (+ 4.2" pre-season) regime on almonds near Fresno, CA, and found the best results with a gradual cutback to 40% ETc by harvest, but a resumption to 60% ETc post harvest. Goldhamer also performed dehorning in almonds as part of another study and found that tree water stress, as measured by predawn water potential, was substantially reduced by this practice, and he has proposed that almonds may only require a total of 12" ETc in order to survive (Goldhamer, personal communication), but to our knowledge there has been little research into this question. It is likely that grower decisions about the best course of action to take for any particular orchard and soil condition will depend on the level of stress being experienced by the trees, particularly for trees on shallow or variable soils. Some trees may require dehorning in order to assure survival, whereas others may not, and even for shallow soils, mechanical pruning/ toping may be sufficient to ensure survival. One potential problem with winter dehorning is that substantial spring regrowth may occur and establish a canopy of leaves that are ill-suited to withstand drought later in the season. One possible approach to avoid this problem would be to wait to apply pruning/toping until the trees are experiencing mild to moderate stress, thus reducing the risk of encouraging unwanted regrowth. Clearly, any test of drought survival strategies must consider both in-season effects on yield as well as carryover effects on bloom and yield for an additional 2-4 years, particularly for severe measures such as dehorning.

Materials and Methods

The trees of this study are located at the Nickels estate (Arbuckle, CA), and are the surface (single line) drip irrigated plots of the Marine Avenue irrigation experiment. A total of 5 replicate plots consisting of 6 rows X 11 trees were established, with 2 of the rows being Nonpareil, bordered on each side by one of three other varieties (Butte, Carmel, Monterey), serving as guards. Each plot consisted of 8 treatments as described in table 1.

Table1. Combination of irrigation and canopy reduction treatments. These treatments will only be imposed in year #1, followed by normal irrigation and cultural practices in years #2 and 3.

Irrigation Treatment	Canopy modification
0 (rainfed)	None
	50% reduction once SWP reaches -15 bars
	50% reduction + Kaolin spray
5" in-season	None
	Kaolin spray
10" in-season	None
	Kaolin spray
Control (100% ETc)	None

The irrigation treatments were based on recent work by Goldhamer, showing that deficit irrigation appears best when spread throughout the growing season. The 5" and 10" irrigation levels were established by replacing drippers in the existing system, but using the same schedule of irrigation timing as used in the control. Applied water is being measured with water meters and direct flow measurements on each dripper, as well as automated sensors for measuring system on time. Grids of 9 neutron access tubes were installed in a single quadrant of one tree in each drought treatment in 4 of the 5 plots. Measurements of midday stem water potential (SWP) are being taken approximately weekly, and soil moisture with neutron probes monthly. Periodic measurements of canopy light interception are also being made. SWP is measured on one central tree in each rep of each treatment (total of 40 trees). Yield was measured at the end of the first season, and dieback, bloom status, and yield will be measured in subsequent years. In years #2 and 3, the intensity of measurement of soil moisture and SWP will be reduced, unless there are indications that the year #1 treatments have caused root system dieback.

Results and Discussion

Because of difficulties managing irrigation during harvest, the amounts of applied water in 2009 at this site were somewhat less than those normally applied, with the control treatment receiving about 80% of full ET (Table 2). Most of this deficit occurred after harvest. The

Table 2. Applied irrigation amounts for each treatment, and the corresponding range in minimum SWP (maximum stress) exhibited by individual trees in that treatment over the season.

Irrigation Treatment	Inches of Water Applied in 2009	Range in Minimum SWP Observed for all Trees Within Each Irrigation Treatment
0 (rainfed)	0”	-29 to -63 bars
5" in-season	3.6”	-24 to -42 bars
10" in-season	7.2”	-24 to -35 bars
Control	30.8”	-19 to -22 bars
100% ETc	38.7"	-9 bars

substantially different irrigation amounts used in this study however, resulted in clear differences in SWP over the season, and as expected, the most stress was exhibited in the non-irrigated plots, least in the fully irrigated plots, and intermediate levels in the 5" and 10" irrigated plots (Fig. 1). SWP was very responsive to individual tree conditions, for instance, a 1" rainfall event near the end of April allowed some recovery in all treatments (Fig. 1). Also, following harvest, the irrigation to one plot of control trees was inadvertently discontinued and irrigation to one plot of 0" trees was inadvertently re-established, both temporarily, and these events were reflected by a sudden decrease in SWP in the control and increase in SWP in the 0" at this time (Fig. 1).

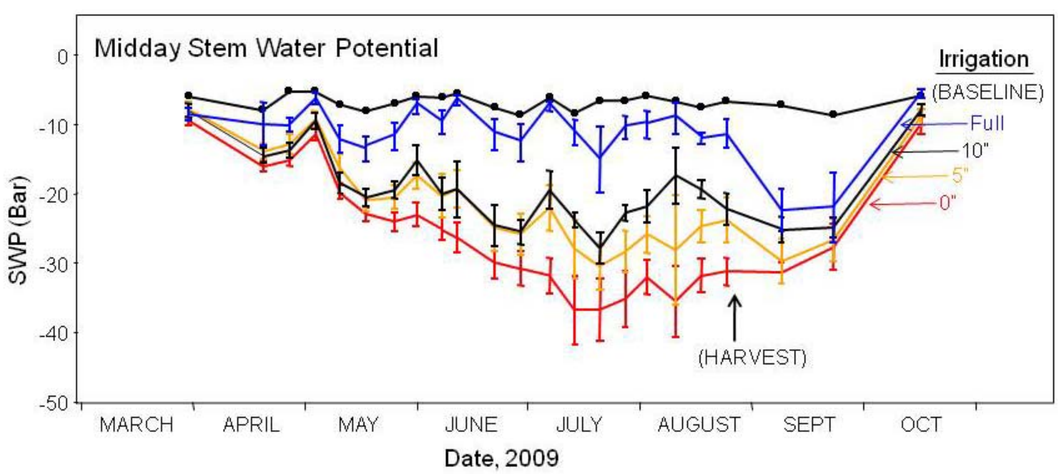

Figure 1. Seasonal pattern in average midday stem water potential (SWP) for non-stressed (baseline) conditions, and for each of the irrigation regimes imposed in 2009. Error bars are approximate 95% confidence limits.

Despite the clear effect of deficit irrigation on treatment average SWP (Fig. 1), substantial tree-to-tree variation in SWP was also observed within each treatment, with some trees in the 0" treatment showing less stress than some trees in the 5" or 10" treatment (Table 2).

It was expected that Kaolin spray and pruning might mitigate the effects of deficit irrigation and that SWP would be higher (less stressed) in these treatments. In the 5"and 10" irrigation regimes, Kaolin spray had no detectable effect on SWP (Fig. 2), but in the 0" (non-irrigated) treatment, both Kaolin and pruning did improve the SWP compared to the controls from June – September, and in combination, their effects appeared to be synergistic (Fig. 3). Whether or not these differences in SWP will be associated with meaningfully less carryover effects in yield will be determined in the 2010 and 2011 seasons.

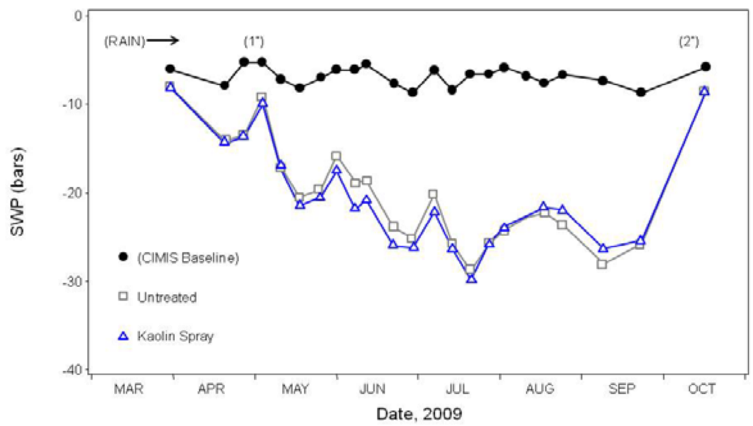

Figure 2. Midday stem water potential (SWP) of Untreated and Kaolin Sprayed trees in the 5" and 10" irrigation treatments showing no reduction in stress due to spraying

A separate statistical analysis of the yield and nut size data was performed for each canopy modification, since it was anticipated that severe pruning (50% canopy reduction) would itself reduce yields substantially. Table 3 shows the results of this analysis, with the only statistically significant results being substantial reductions in both tree yield and nut size in the non-modified canopy trees under deficit irrigation, and a slight reduction in nut moisture content in the fully irrigated trees as compared to the irrigation deficit trees. The latter result was somewhat surprising, but the nuts from all treatments had less than 7% moisture content, and hence moisture was not an issue in any treatment. Since the selection of canopy modification treatments were necessarily different in the different irrigation treatments, Table 3 can also be used to evaluate the effects of pruning and kaolin spraying for the same irrigation, but there were no statistically significant effects of canopy modification within an irrigation treatment, and in no case was there any evidence of an

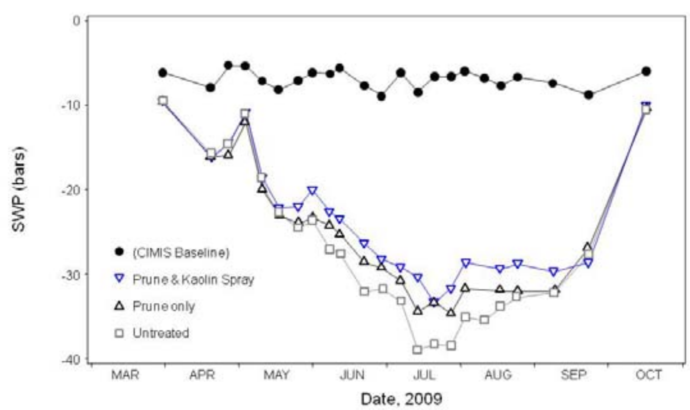

Figure 3. Midday stem water potential (SWP) of Untreated, Pruned (50% canopy reduction), and Pruned & Sprayed trees in the 0" (rainfed) treatment showing some reduction in stress in the June – September period due to pruning and spraying.

Table 3. Final yield and nut size analysis (corrected to 7% moisture) and calculated number of nuts per tree and kernel % moisture after bin drying of whole harvest samples. Means followed by different letters are significantly different at the 5% level. No following letters indicates no significance. Numbers in parentheses are values for single trees in the 5" and 10" irrigation plots that were pruned inadvertently.

Irrigation		Canopy Modification			
		None	Sprayed	Pruned	P+S
Yield (Lbs/ac)	Full	2224 a			
	10"	1890 ab	1860	(1290)	
	5"	2020 ab	1760	(1160)	
	0"	1030 b		860	590
Nut Size (g/nut)	Full	1.16 a			
	10"	1.04 ab	0.90	(1.11)	
	5"	0.97 b	0.95	(0.90)	
	0"	0.72 c		0.79	0.77
Nuts per Tree	Full	7650			
	10"	6810	7560	(4230)	
	5"	7800	6740	(4710)	
	0"	5240		3980	2850
Kernel % Moisture	Full	3.68 a			
	10"	4.29 b	4.39	(4.21)	
	5"	4.41 b	4.45	(4.10)	
	0"	4.38 b		3.96	4.27

improvement due to canopy modification. The only indication of a trend in benefit was that nut size was improved slightly (but not significantly) in the 0" irrigation by pruning, but this was at the expense of lower number of nuts per tree, and so yield was lower.

One advantage of recording SWP for individual trees over the season is that yield and nut size can be related to SWP for all treatments collectively. Figure 4 shows the relation of yield and nut size to SWP for all irrigation treatments, and it is clear from this figure that yield and nut size were more related to individual tree SWP than to the irrigation treatment itself. That is, there were some trees which had the same SWP and same yield and size, even though they were subject to different irrigation treatments. A large influence of SWP on nut yield and size may be one reason why many of the differences in Table 3 were not significant, particularly that pruning did not significantly affect yield. In order to account for the effects of canopy modification independent of SWP, Table 4 shows the "least squares means," which are adjusted to the average level of SWP across treatments. These results clearly show that, as expected, pruning reduced yield, but that spraying had no effect.

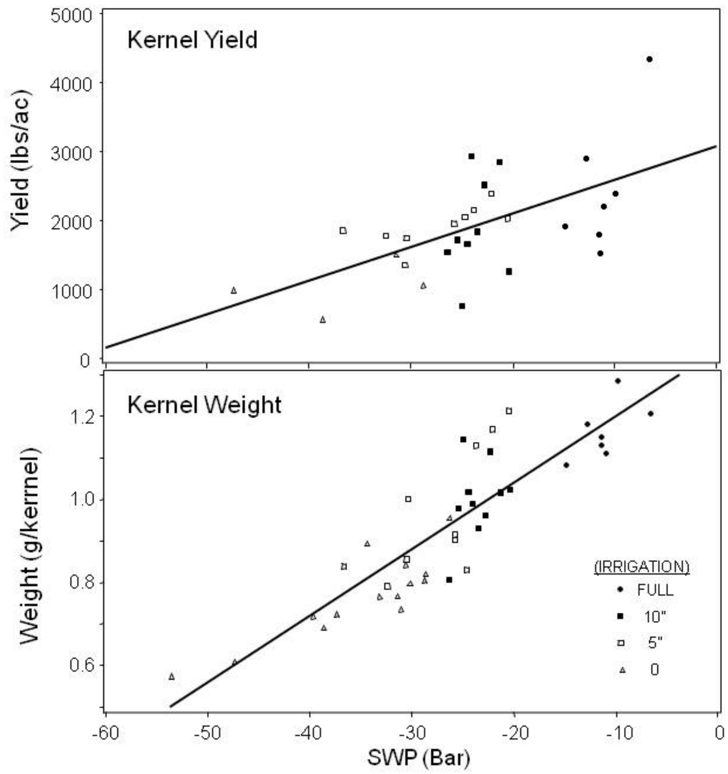

Figure 4. Relation of yield and kernel weight to the average SWP during July for each individual tree of the study. For the kernel weight analysis all trees were included, but for the yield analysis only non-pruned trees were included.

Table 4. Least squares means (adjusted to the same level of SWP) for each canopy modification treatment. Means followed by different letters are significantly different at the 5% level. No following letters indicates no significance.

Canopy Modification	Yield (lbs/ac)	Nut Size (g/nut)	Nuts/Tree	Kernel % Moisture
None	1760 a	0.95	6740 a	4.25
Sprayed	1890 a	0.95	7240 a	4.40
Pruned	1120 b	0.96	4260 b	4.11
Pruned & Sprayed	630 b	0.91	2580 b	4.00

Literature Cited

Goldhamer DA, and Smith TE.1995. Single-season drought irrigation strategies influence almond production. Cal-Ag. 49:19-22.

Proebsting ELJ and Middleton JE. 1980. The Behavior of Peach Prunus-Persica and Pear Pyrus-Communis Trees under Extreme Drought Stress. JASHS 105: 380-385.

Impacts of Irrigation and Pruning on Canopy Management and Potential Productivity in Walnut

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Introduction

The amount of the total incoming light that a tree canopy can intercept, and the efficiency of conversion of that light energy into the desired crop sets an upper limit on productivity. For about 10 years, we have been working on developing the yield potential of walnut as it is related to midday canopy light interception and how irrigation and pruning can influence that relationship.

Background

We have been collecting midday canopy light interception data on walnuts and trying to relate these data to yield potential. However, the rate of increase in canopy area in a developing orchard is dependent on nutrient, irrigation and pruning management. Our data suggests the relative importance of these factors (from most to least) is irrigation/pruning/nutrient management. The influence of irrigation and pruning will be addressed here.

Irrigation Management During Orchard Development

There is an upper limit to the tons per acre of walnuts that can be produced for a given level of midday canopy light interception. Figure 1 shows the relationship between midday canopy light interception measured in mid-summer and the associated yield that season. The diagonal line from 0 yield at 0 percent light interception to 5 tons/acre at 100 percent light interception represents the upper limit for sustained productivity. Although there are some points above this line, based on previous experience those same orchards will likely be below the line the following year (or were below the line the previous year). The potential production of a walnut orchard is about 0.5 tons per acre for each 10 percent of the incoming midday light that it can intercept.

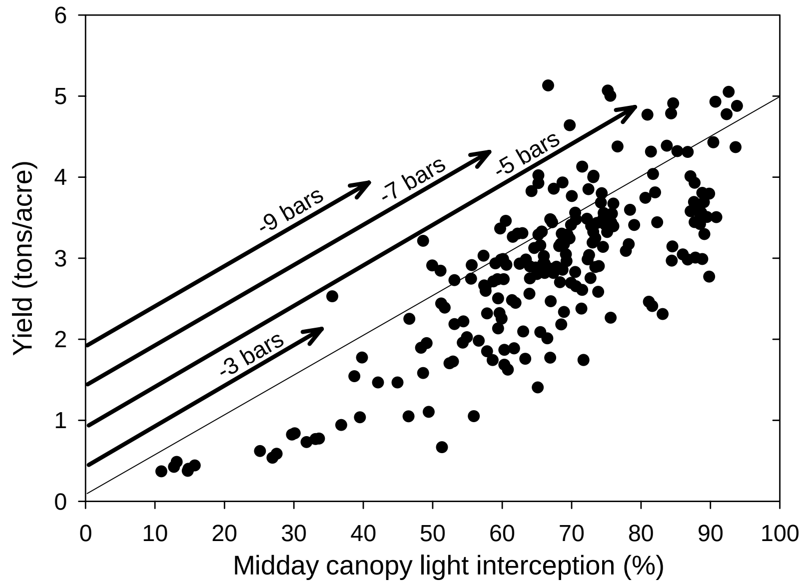

Figure 1. Relationship between midday canopy light interception and yield potential for walnut. Data is for statewide light bar survey 2009. Arrows indicate estimated rate of canopy development for first 10 years of orchard life at different seasonal average midday stem water potentials levels.

The plant pressure chamber provides a sensitive means of assessing plant water status and tree growth potential in walnut. The arrows in Figure 1 indicate the estimated rate of canopy development over 10 years for different levels of seasonal average midday stem water potentials. Keeping an orchard near, but not wetter than, the fully watered baseline which would be about -4.5 to -5 bars over the season results in the fastest rate of canopy development (-5 bar arrow in Fig.1). Any amount of stress will decrease the rate of canopy development and result in potential loss in yield as shown by the -7 and -9 bar seasonal average arrows in Fig. 1. Keeping the orchard wetter than the fully watered baseline (indicated by -3 bar arrow in Fig. 1) can result in tree stunting and disease problems that can be even more devastating than the slowing of canopy development that occurs as a result of a water deficit. This figure points out the importance of water management in canopy and yield potential development in walnut. In general, the rate of midday canopy light interception for a well managed walnut orchard is about 7-10% per year with the orchard reaching it's optimal level of midday canopy light interception near 80% in about 8 years with a production potential of about 4 tons/acre. In the example in Figure 1, the orchards kept at -5, -7, -9 and -3 bars would have had potential cumulative yields of 21.6, 16.2, 10.8 and 9.5 tons per acre respectively over the first 10 years.

Canopy Management During Orchard Development

Pruning practices also can influence the rate of canopy development, and hence yield potential in walnut. The common pruning practice in lateral bearing walnuts is to remove about one third of the previous years' growth on permanent scaffold limbs during the dormant season. The common wisdom is that this reduces crop load and stimulates more rapid canopy development. However, a research study on Howard walnuts conducted from 2003 to 2010 has shown that the impact of crop load on growth is relatively minor and that unpruned trees can grow and produce as well as pruned trees under the conditions of this trial (Lampinen et.al, 2010). Figure 2 shows the midday canopy light interception for the various pruning and fruit removal treatments. There were no significant impacts of either the pruning or fruit removal treatments on midday canopy light interception for the 6 years of data collected.

Since pruning impacts crop load, there are short term impacts of pruning practices on crop load. Fig. 3 shows the yield for the same orchard trial shown in Fig. 2. Neither pruning nor fruit removal practices had a significant benefit in terms of increasing long term cumulative yield (Fig. 3).

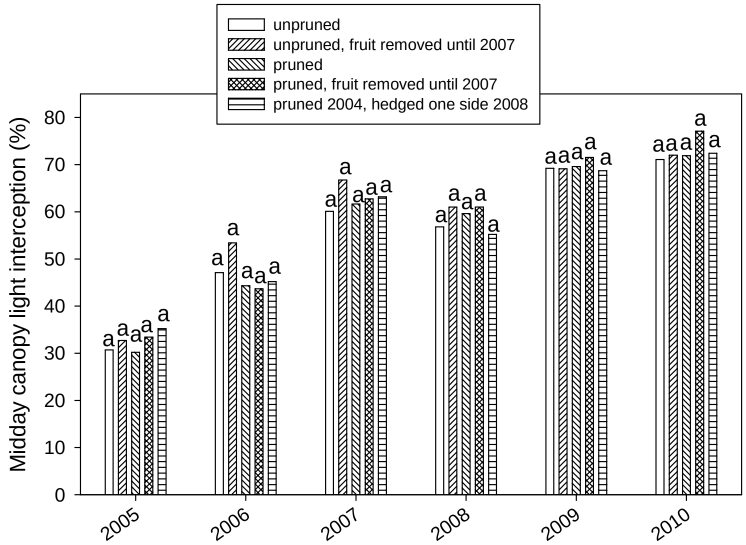

Figure 2. Midday canopy light interception measured on during late June or early July each year. Letters indicate a significant difference (5% level of significance) among treatments within a given year. Data is for the Howard walnut pruning trial at Nickels Soil Lab (Lampinen et.al, 2010).

Another study looking at pruning practices in walnut is currently being carried out in an adjacent Chandler orchard at Nickels Soil Lab (DeBuse et.al., 2010). It is too early to draw any definite conclusions from this trial but preliminary results suggest that pruning is also not accelerating canopy development in Chandler walnut (as measured by midday canopy light interception). Table 1 shows the midday canopy light interception which was significantly greater for the unpruned compared to the heavily pruned trees at the early July measurement date shown. Yield and yield efficiency (expressed as yield per unit light intercepted) were significantly higher for the unpruned treatment compared to either the heavily pruned or minimally pruned treatments (Table 1).

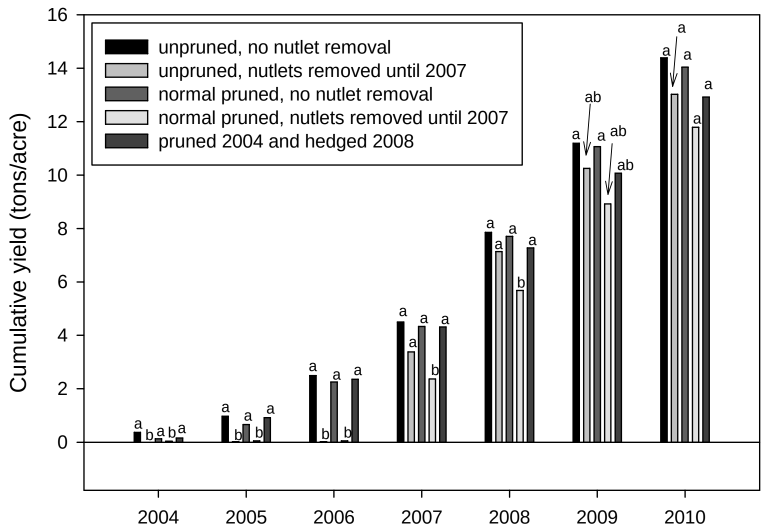

Figure 3. Cumulative yield by treatment and year for Nickels Soil Lab Howard pruning trial. Letters indicate significant treatment difference at 5% level of significance within a year. Data is for the Howard walnut pruning trial at Nickels Soil Lab (Lampinen et.al, 2010)

Table 1. Midday canopy light interception (measured in early July), yield and yield per unit light intercepted for different pruning treatments at Nickels Soil Lab Chandler pruning trial 2010. Letters indicate significant difference at 5% level of significance for pruning treatments down the column.

Variety	Treatment	Midday canopy light interception (%)	Yield (tons/acre)	Yield per unit PAR intercepted
Chandler	Heavily pruned (1)	17.4 b	0.14 c	0.008 c
	Minimally pruned (3)	22.3 ab	0.33 b	0.014 b
	No heading/pruning (4)	24.1 a	0.73 a	0.030 a

Discussion

Both irrigation and pruning practices can impact canopy development and potential productivity. For each bar of seasonal average midday stem water potential stress that a walnut tree experiences, there will be a corresponding slowing of canopy development. This will translate to decreased yield potential in not only the following season but in the following years as well until the orchard has filled in its' allotted space. However, an orchard that runs excessively wet (wetter than the fully watered baseline) will also experience a negative impact on canopy development and yield potential, so it is important to not over-irrigate as well. The observations of the authors suggest that the negative impacts of excessive water tend to be worse than the impact from lack of water since excessive water leads to decreased canopy development, decreased tree health and eventually tree loss. The impacts of pruning are less clear. Results from a 7 year pruning trial on Howard walnuts done at Nickels Soil Lab (Lampinen et.al, 2010) suggest that while pruning did not have a negative impact on canopy development or yield compared to an unpruned treatment, it also did not have any beneficial effects. If the costs of pruning and grinding/burning of the prunings in included, the benefits of the unpruned treatment would likely prevail.

A well managed walnut orchard can increase in midday canopy light interception at a rate of about 7-10 percent per year. At this rate, the orchard would reach an optimal level of midday canopy light interception at about 8 to 12 years of age. At this point, the potential production is about 4 tons/acre. The average canopy development for our statewide survey in 2009 and 2010 was about 7% per year. This would mean that it would take about 11 to 12 years for an average orchard to reach 80% light interception.

However, it is important to point out that these results would likely vary under different management regimes and with different soil types. Further work is needed to see if these same results would occur under different conditions.

Literature Cited

DeBuse, Carolyn, John Edstrom, Janine Hasey, and Bruce Lampinen. 2010. Walnut hedgerow pruning and training trial. Walnut Research Reports 2009. Pp. 115-121. (http://walnutresearch.ucdavis.edu/2009/2009_115.pdf)

Lampinen, Bruce, John Edstrom, Dave Ramos, Sam Metcalf, Claudia Negron, and Stan Cutter. 2010. Comparison of growth and productivity of pruned and unpruned young 'Howard' walnut trees as impacted by crop load. Walnut Research Reports 2009. Pp. 121-131. (http://walnutresearch.ucdavis.edu/2009/2009_123.pdf)

Trends in Pumping Efficiency

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Introduction

The Center for Irrigation Technology at California State University of Fresno (CIT) has operated a program for improving pumping efficiency in California continuously since 2001. It began as the Agricultural Peak Load Reduction Program with funding from the state's general tax fund under the direction of the California Energy Commission. That program ran until 2003. CIT was also an original participant in the California Public Utilities Commission's "Third Party" process and started the Agricultural Pumping Efficiency Program (APEP or Program) in 2002 with funding from the Public Goods Charge (PGC) under their auspices. (The PGC is a fee that all customers of investor-owned utilities pay to support energy efficiency programs in the state. The Third Party process allows companies other than the investor-owned utilities in California to implement energy efficiency programs using the PGC.) Since 2006, CIT has operated APEP under the direction of the Pacific Gas and Electric Company but still using funds from the PGC.

The program is now known as the Advanced Pumping Efficiency Program. Eligibility extends to agricultural, large turf irrigators (mainly golf courses), municipal water agencies, and private water companies. It specifically does not work with industrial process pumps, residential pumps, or primary and secondary sewage systems. It is currently funded through 2012.

APEP offers educational seminars, technical assistance, subsidized pump efficiency tests, and cash incentives retrofit pumps so as to increase efficiency. A pump has to be operational to be eligible for a retrofit incentive (i.e., the Program does not provide assistance to fix a broken pump.) A retrofit must involve repair or replacement of either or both of the pump bowl and impeller. Since 2002, APEP has provided approximately $3.7 million in subsidies for over 20,500 pump efficiency tests and approximately $4.5 million in cash incentives for 1,180 pump retrofits.

The Pump Efficiency Test

The pump test is intended to provide pump-specific information regarding performance. The subsidy is intended to encourage the practice. There are two sections to an APEP test report, the measurements and calculations and the pumping cost analysis.

The most important part of the test results as far as the Program is concerned is the pumping cost analysis (see Figure 1). It presents an estimate of the current pumping costs and the potential reduction that could occur with a pump retrofit. Motor efficiencies are known (although in the case of older motors that have been rewound one or more times there is some uncertainty). Pump performance curves from the manufacturers indicate potential bowl efficiencies. Thus, we can estimate the performance of a pumping plant in good operating condition and operating at the design condition. The cost analysis is intended to provide the information that will allow the owner/operator to make an objective decision as to when it will be profitable to retrofit the pump.

Please pay careful attention to the assumptions. The estimated savings are only valid for the assumptions made and conditions measured during the pump test.

	EXISTING CONDITIONS	ASSUMED IMPROVED EFFICIENCY	
1. Overall pump efficiency:	39%	65%	
2. Motor loaded at:	103%	105%	
3. Flow rate (gpm):	1,750	2,250	
Pumping level (feet):	240	309	
Discharge Pressure (psi):	<u>2.0</u>	<u>2.0</u>	*NOTE: TDH = Pumping Level +*
4. Total Dynamic Head (feet):	245	313	*(2.31 x Discharge Pressure)*
5. Acre-feet Pumped/yr:	467	467	
6. Hours of Operation/yr:	1,450	1,127	**ESTIMATED SAVINGS FROM IMPROVED EFFICIENCY**
7. Kilowatt-hours per Acre-foot:	644	493	**151**
8. Estimated Total kWh per Year:	300,748	230,298	**70,450**
9. Average Cost per kWh:	$0.13		
10. Average Cost per hour:	$27.00	$26.55	**$.45**
11. Average Cost Per Acre Ft.:	$83.72	$64.09	**$19.63**
12. Estimated Acre Ft. per Year :	467	467	
13. Operating Hours per Year:	1,450	1,127	**323**
14. Overall Pumping Efficiency:	39%	65%	
15. Estimated Total Annual Cost:	*<u>$39,097</u>*	*<u>$29,930</u>*	***<u>$9,167</u>***

Figure 1 – Pumping Cost Analysis Section of an APEP Pump Efficiency Test Report

This supports the logic behind the Program's existence, which is:

1. A pump retrofit is not a trivial cost

2. Absent information to the contrary, pumps are only retrofitted when they either physically break or the combination of flow/pressure output is not enough to fulfill the pump's purpose

3. The information provided by the pump test is intended to show that a pump retrofit, before failure, will be profitable. Thus, overall pumping efficiency in California will be improved and energy used for pumping will decrease.

Statistics

Obviously, a measure of APEP's success would be a gradual improvement in OPE in California. Figure 2 is a graph of Overall Pumping Efficiency for electrical-powered pumps for four program "cycles". APEP has not provided pump tests for pumps of under 25 horsepower since the end of the 2003-2005 cycle.

No effort is made to ascertain the statistical significance of any of the numbers presented as they were not obtained under controlled conditions. However, there appears to be an overall trend of improving OPE, albeit with a falloff in the 2006-2008 cycle. There may be a couple of reasons for this falloff. First, the program was off-line from January to October of 2006 while new funding contracts were being negotiated. This decreased Program recognition and the momentum that was built up from 2002-2005. It was early 2007 before APEP was fully operational again. Probably more important though, as far as the pump testing component is concerned, it became much more important to test pumps that hadn't been tested before (as a way of more efficient use of the available funding). Thus, there probably were more pumps that hadn't been retrofitted in some time being tested in the 2006-2008 cycle.

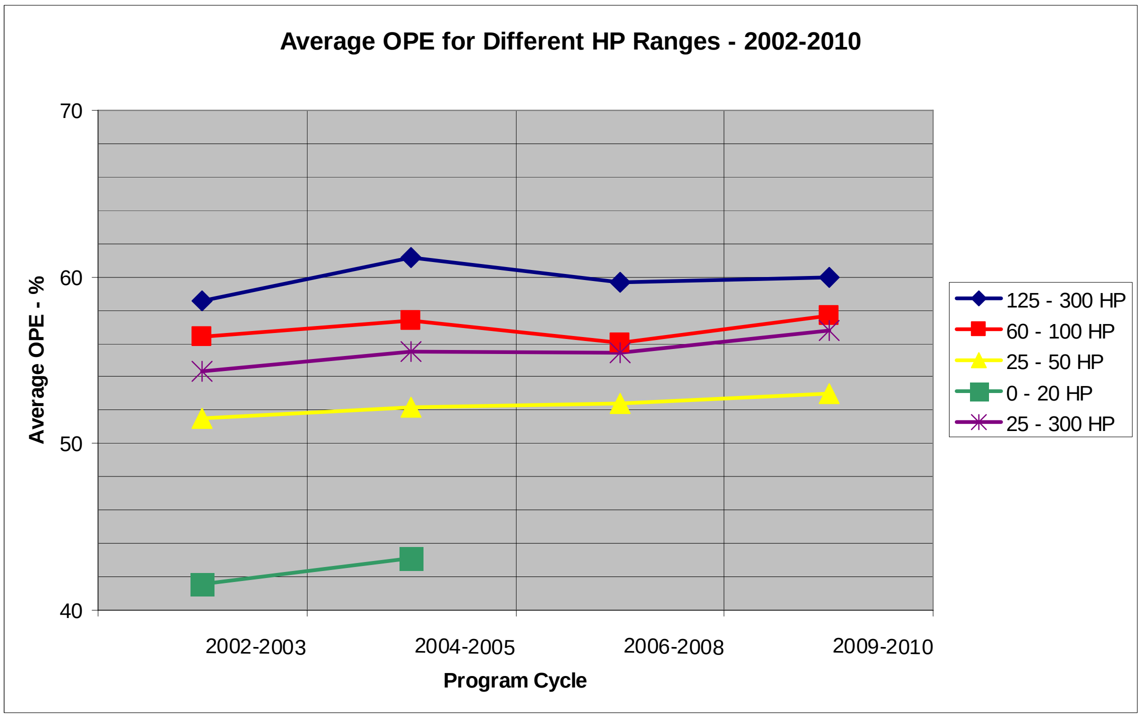

Figure 2 – Average OPE for Different HP Ranges – 2002-2010

At a cursory glance it would appear that OPE has improved by about 2 percentage points in the time 2002 through 2010 (using the average of all pumps 25 – 300 horsepower). This may not seem like much but CEC reported in 2005 that the water infrastructure (delivery, pressurization, purification, sewage treatment, etc.) in California consumed nearly 20% of all electrical energy. In the same report, 2004 electrical energy use in California was estimated at some 271,000 GWH. Thus, assuming that the APEP database is a fair sample then it would seem that the program has been a major asset to California.

However, it is pointed out that to a certain extent the sample, large as it is, is somewhat self-selecting as APEP does not "choose" the participants. Rather, the participants choose to take advantage of the Program. To the extent that APEP participants might represent those that are more attuned to the need for energy efficiency in the state, or are more sensitive to the economics of pumping, the results are biased.

There is also the fact that participation in the early cycles of APEP would have been from pumps that hadn't been tested and/or retrofitted in some time. As the specific data was presented to pump owner/operators, the sub-standard pumps were the first retrofitted. As the population of substandard pumps declined, it would be expected that the average OPE would improve.

Some may note the disparity between the 20,000+ pump tests and the 1,150+ retrofits. In the energy efficiency "universe" there is a phenomena known as "spillover". This is a situation where an energy-user learns of the cost-effectiveness of an energy efficiency measure through the efforts of a particular program, in this case the pump retrofit. However, the user chooses not to participate in the program, which might be for any number of reasons including perceived time needed to complete paperwork or fear of being in "just another database". Thus, the influence of the 20,000+ pump tests provided by APEP very likely extends much farther than the 1,150+ retrofit projects would indicate.

Indicated OPE Improvements from a Pump Retrofit

Obtaining an incentive rebate requires both pre- and post-project pump tests to be submitted with the application. APEP does have some rather loose timing criteria so the tests are not performed "just" before a project and "just" after- there may be months, and possibly even a year or more involved.

Program Cycle	2002-2003				2004-2005				2006-2008				2009-2010			
	Pre-OPE	Post-OPE	% Improv	Number of Pumps	Pre-OPE	Post-OPE	% Improv	Number of Pumps	Pre-OPE	Post-OPE	% Improv	Number of Pumps	Pre-OPE	Post-OPE	% Improv	Number of Pumps
BY TYPE																
All District/Agency Pumps	37%	62%	68%	6	42%	48%	14%	4	50%	66%	32%	76	50%	66%	32%	89
All Ag/Turf Pumps	36%	59%	64%	55	41%	61%	49%	74	42%	62%	48%	182	45%	65%	44%	269
BY HORSEPOWER																
0-25 HP	29%	54%	86%	16	33%	52%	58%	20	39%	57%	46%	23	41%	58%	41%	21
26-50 HP	38%	58%	53%	18	44%	62%	41%	17	42%	61%	45%	66	43%	62%	44%	92
51-150 HP	41%	63%	54%	21	46%	66%	43%	36	46%	65%	41%	143	47%	66%	40%	195
151+ HP	35%	68%	94%	6	30%	53%	77%	5	50%	68%	36%	26	51%	70%	37%	50
ALL PUMPS	36%	60%	67%	61	41%	60%	46%	78	45%	63%	40%	258	46%	65%	41%	358

Table 1 – Average Pre-Project and Post-Project OPE for Various Types of Pumps and Horsepower Ranges for Four APEP Program Cycles

Table 1 shows the average pre- and post-project OPEs for different Program cycles (note the small sample sizes in some cases). There could be several reasons for the overall trend towards higher pre-project OPE (from 36% to 46% for ALL PUMPS) and lower average percentage improvement in OPE (from 67% to 41% for ALL PUMPS):

1. The early cycles of APEP were working with a population of pumps that had not been tested or had cash incentives available for retrofits for some time. Thus, the "bad actors"

were taken care of early in the program's operations and pre-project OPEs would tend to increase.

2. There are two reasons why a pump becomes inefficient, a) it is physically worn and b) it is forced to work off its design operating condition (the combination of flow and total dynamic head where it works most efficiently). The recent multi-year drought in California, coupled with decreases in surface water supplies to agriculture has forced more people to use their wells, in a time when pumping water levels are declining at an increasing rate (due to the drought and also because more are forced to pump). Thus, many of these pumps are now operating off their design condition. It may well be that pump owner/operators in these situations are trying to "get ahead of the game" and retrofitting earlier, in conjunction with dropping the level of pump bowls to account for the declining pumping water levels. Thus, the pre-project OPEs would tend to rise.

3. As the cost of energy increases, it is natural that pumps may be retrofitted at higher and higher pre-project OPEs. However, always note that two possible reasons for higher energy prices to occur are a) energy shortages and b) a general inflation. A general inflation will also generally increase the cost of a retrofit and thus, would tend to slow the trend (i.e., the benefit/cost ratio may tend to stay the same in a general inflation).

4. During 2005, the eligibility criteria for the Program expanded to include municipal and other agency-type pumps. These generally have significantly more hours of operation than agricultural pumps and thus, the economics favor earlier retrofits at higher pre-project OPEs.

5. Finally, post-project OPEs tend to have an upper limit and thus, as the pre-project OPEs increase it is natural that the percent improvement in OPE will decrease.

Experiences with an APEP-type Program with Diesel-Powered Pumping Plants

CIT also implemented a pilot program for diesel-powered pumping plants using funding from USEPA Region 9 and Valley CAN, a private funding corporation. Except for having no educational component this pilot program was exactly similar to APEP and provided both subsidized pump efficiency tests and incentives for retrofit of inefficient pumps. The final report of this program can be found at www.pumpefficiency.org.

This program provided 58 pump efficiency tests with a resulting 17.1% average OPE. It is felt, given a diesel engine's thermal efficiency that 22-24% should be attainable.

The program funded eleven pump retrofit projects with both pre- and post-project pump tests. These results are summarized in Table 2

	Before Retrofit	After Retrofit	Percent Improvement
OPE	14%	23%	64%
Water flow – GPM	742	1025	38%
Brake HP Input	80	86	
Engine RPM	1,734	1,696	
Input HP-hours/Acre-foot water pumped	2,237	1,319	-41% (a decrease in energy use)

Table 2 – Summary of results from eleven diesel-powered pumping plant retrofits

The results of this program indicated that dramatic improvements in diesel-powered pumping plant performance could be available. Reasons for this would include:

1. No systematic program for improvement of diesel-powered pumping plant performance improvement has ever been implemented in the state.

2. Diesel-powered pumping plants can compensate for loss of bowl efficiency to a certain extent by increasing engine speed, thus further delaying a pump retrofit.

In Summary

APEP as been in operation, albeit with a significant lull in early 2006, from 2002 to the present. The intent of the program is to improve overall pumping efficiency for a large portion of water pumps in California. It has provided approximately $3.7 million in subsidies for over 20,500 pump efficiency tests and approximately $4.5 million in cash incentives for 1,180 pump retrofits. Data indicate a slowly improving trend in OPE, possibly in the range of 1.5 to 2 percentage points in OPE from 2002 through 2010. It is noted that a 2005 CEC report to the legislature estimated that almost 20% of the total state's electrical consumption of 271,000 GWh was being used to pump and sanitize water. Thus, the 1.5-2 points, if an accurate measure, would represent a significant energy savings to the state. It is expected that the trend to gradually improving OPE will continue as energy costs increase. However it will level off at some point based on the prevailing economic tradeoffs between the capital costs of the retrofit versus annual energy cost savings.

Literature Cited

2005 Integrated Energy Policy Report, California Energy Commission, report CEC-100-2005-007-CTF, November 2005.

American Society of Agronomy
California Chapter

Session IV
Ag Certification Systems

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LGMA GAP Audit Program for Compliance and Marketing

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Introduction

The California Leafy Green Marketing Agreement (LGMA) was formed in 2007 in response to a foodborne illness outbreak with spinach that was traced to a California based handler of lettuce and leafy greens. This was a major outbreak, resulting in 3 deaths and more than 100 illnesses. This outbreak followed multiple outbreaks over preceding seasons which were linked to lettuce and leafy greens and the industry realized that something beyond what was being done under current conditions was needed. Without action, it was clear that the FDA would take action to implement laws and regulations that could have major consequences to the industry.

In an unprecedented response, the industry, government and academia came together to tackle the problem. Working on multiples fronts, this cross section of disciplines began developing what would become the "Commodity Specific Guidelines for the Production and Harvest of Lettuce and Leafy Greens" or as it's commonly known, the "metrics". On the administrative side, discussion began with the California Department of Food and Agriculture's Division of Marketing to establish the program which would provide the organization and structure to administer the program. To meet a very short time frame, the program was organized as a voluntary "marketing agreement" and successfully implemented in a matter of months. An action which normally can take many months or years.

In describing the program in very general terms, the" LGMA, operating with oversight from the California Department of Food and Agriculture, the LGMA is a mechanism for verifying through mandatory government audits that farmers follow accepted food safety practices lettuce, spinach and other leafy green products". Now in its 4th season, the LGMA is a success, with the program covering more than 99% of all lettuce and leafy greens produced and shipped from California through its GAP Food Safety Program

Acceptance: Regulatory and Marketplace Credibility

The LGMA GAP Food Safety Program has wide acceptance throughout the market place and is acknowledged as a model program by State and Federal regulatory agencies. This has been achieved by; 1) establishing and maintaining collaboration between government and industry, incorporating best practices and sound science and ensuring continuous improvement through education and experience. Underscoring these steps is the basis for the overarching goal of the program which is to "establish a culture of food safety on the farm".

The program is viewed as both experienced and proven on several factors. These include; 1) regular and consistent audits by government inspectors; 2) widespread compliance with food safety practices and 3) real penalties and consequences for non-compliance. Another program strength is based upon strong collaboration between government and farming communities. Other considerations based upon collaboration includes; 1) the broad participation of diverse geographies, farming practices and membership; 2) overwhelming industry commitment to the program and 3) oversight from the government for its administrative and field operations.

The "metrics" is based upon best practices and sound science and incorporates food safety principles of hazard analysis and risk mitigation. They are designed to reduce risks for a specific commodity and on individual farms. The program's Technical Committee addresses critical issues and concerns and reviews proposed changes to the standards that evolve with new information in a very short timeframe.

A final consideration is the philosophy that there is continuous improvement to the program. This goal is obtained by; 1) progressive industry training and education programs to improve compliance; 2) frequent inspections and corrective actions on the farm; 3) using results to identify targeted research and training needs and 4) having a system that is adaptable for varying farm operations and commodities.

Program Components

The (5) major components of the LGMA GAP Audit Program are; 1) audit; 2) auditors; 3) audit checklist; 4) compliance and 5) certification. Collectively, they ensure that all LGMA member companies are subject to mandatory government audits on a regular and random basis to ensure to ensure that LGMA-accepted food safety practices are being implemented and followed. The audit is the cornerstone for the success of the program and provides the basis for establishing the credibility with buyers, consumers and government regulatory agencies. By ensuring that lettuce and leafy greens have met the rigorous standards established under the marketing agreement, consumers and buyers have confidence that the product is safe and wholesome and the regulatory agencies recognize that the mandatory requirements established in the "metrics" are being met.

There are key provisions within the <u>audit</u> that ensure success include; 1) clear and distinct handler and grower responsibilities; 2) multiple audits during the growing season; 3) mandatory unannounced audits; 4) critical auditor observations that result in corrective actions being developed and implemented on an on-going basis and 5) operational provisions required by the USDA and CDFA Marketing Program.

The <u>auditors</u> are CDFA employees who are trained and licensed by the USDA. A strength is the government auditors are dedicated to the LGMA program which provides a high degree of consistency and uniformity. In addition, they have extensive audit related training and experience and must comply with certain requirements specified by CDFA and USDA.

The <u>audit checklist</u> is the tool used by the auditors to conduct the audits. It is divided into (6) categories that address all LGMA accepted food safety practices. Each category (as applicable) is covered during the audit, providing a thorough and comprehensive audit. The individual categories include; 1) general requirements; 2) water use; 3) soil amendments; 4) harvest assessments; 5) work practices and 6) field sanitation.

General Requirements identifies what each written food safety program must include. The written program (manual) is a pre-requisite and must be presented for review at the beginning of the audit. The manual must include a current growers list, the grower's traceability program, a designated person(s) who is responsible for all aspects of the program and a provision that person(s) must be available for contact on a 24/7 basis.

Water Use addresses issues associated with water quality, source, and testing. Examples required under the metrics include; 1) a detailed ranch map with water distribution systems; 2) irrigation water test results for first use on post germinated fields; 3) testing records for sampling dates, sample location and time of sample; 4) lab accreditation and testing methodology; 5) source of water; 5) tests results for water used for pre-harvest foliar and non-foliar applications; 6) test results for post harvest direct application to product; 7) records showing actions taken for all non-compliance situations and 8) quality of water used in equipment cleaning.

Soil Amendments address use of composted manure, heat treated product that contains animal manure and non-synthetic crop treatments. Examples required for soil amendments include; 1) time of application; 2) testing to pathogens; 3) testing methods; lab accreditation and 4) sampling plans that may apply to all types of soil amendments.

Harvest Assessments address issues associated with animal activity, adjacent land use, recent field history and unusual events. Of particular concern is conducting a pre-harvest and daily harvest assessment to assess the condition of fields up to 7 days prior to harvest and the daily harvest assessment which is conducted immediately prior to the start of harvesting. Both assessment includes a walk-around of the field that will be harvested and consider; 1) multiple circumstances that indicate the presence or evidence of animal activity; 2) flooding and other potential sources of contamination and 3) recorded actions by designated person taken in response to findings.

Work Practices address issues associated with field sanitary facilities, worker practices, and worker health practices. Examples of requirements for worker practices include; 1) written policies for all employees and visitors to field locations hygiene rules; 2) a documented field sanitary facility program; 3) written worker practices program and 4) written worker health practices program.

Field Sanitation addresses issues associated with field activities, harvest activities, work practices, use, soil amendments, environmental factors and field sanitation. In the course of the audit, the auditor may notice activities or circumstances that may be general in nature but are deemed to pose a potential risk of contamination. Examples that fall under this category include; 1) written field activity SOP covering cross-contamination opportunities; 2) written harvest activity SOP that addresses individual responsible for harvesting activities and conducting assessments and 3) other SOPs addressing required information for harvesters and harvesting equipment, cleaning and sanitizing equipment, chemical usage and storage, overnight storage, container use, sanitary operation of equipment and response plan for spills and other emergencies

Penalties and Compliance

This is the enforcement arm of the program and there consequences for failure to comply with its requirements. Since its inception, more than 2200 citations have been issued for non-compliance. There are (3) levels of violations which designate the severity of the violation. They are minor infraction, minor deviation and major deviation. There is 4th category which is only applied when a situation arises that opposes an immediate threat to public health or in the case of repeated failure to address and correct violations as required. In these cases, the handler is referred to the LGMA Compliance Committee for consideration. The committee evaluates the case and makes a recommendation to the LGMA Advisory Board for decertification.

The number of citations issued is proof that the program takes violations seriously and violations for minor and major deviations must have a corrective action developed and submitted to the Compliance Officer for approval. Once approved, the corrective actions must be implemented within the required time frames for the respective violations. It should also be noted that decertification is a strong deterrent since good standing with the LGMA is required by Canada and Mexico for shipping into their countries. Decertification actions are also posted on the LGMA website; alerting buyers to handlers have been taken of the certified list.

Consumer Research

The LGMA contracted for a consumer research study to gauge consumers concerns for food safety, consumption habits following recent outbreaks, who best to trust to ensure safe food and importance of collaboration. The results of this April 2010 survey to 800 people were revealing in demonstrating important opinions expectations regarding food safety.

When asked if you have concerns for food safety, 76% of those responding stated they had some level of concern, while 41% stated that they are very concerned about it. When asked about any changes they have made because of food safety concerns 49% reported they had stopped or reduced consumer of different products. Within that group 28% mentioned beef/ground beef, 11% mentioned vegetables, 8% percent mentioned spinach, 7% mentioned lettuce and 6% mentioned tomatoes. When consumers were asked who they trust best to address food safety, 49% mentioned farmers, 43% mentioned USDA and 35% mentioned FDA. In addition, 86% of respondents stated that farmers and the government need to work together to address food safety issues.

Summary

The LGMA GAP Audit Program is a comprehensive, effective and efficient food safety program that has been recognized as a model by government regulatory agencies. Through enforcement by mandatory, government performed audits, compliance with requirements in the marketing agreement is extremely high and can be used as an effective marketing tool. The components of the program are adaptable and can be scaled to any size operation, addressing concerns about the potential high costs associated with implementing a food safety program.

The program will continue to work to improve and increase its effectiveness. And as we move forward with pending legislation and regulations that will rewrite food safety requirements, the industry must be ready to embrace proven programs and practices the incorporate food safety into their operations.

Improving Nutrient Management: The Role of Certified Crop Advisors

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History

The Certified Crop Advisor (CCA) program began in 1991 as leaders from the agricultural industry, regulatory agencies, and universities recognized the need to establish professional standards for agronomists. The American Society of Agronomy (ASA) provided the leadership and organization to set standards for knowledge, experience, ethical conduct, and continuing education that would result in enhanced agronomic professionalism. Although the International CCA program is administered by the ASA, the program is run by State, Provincial, and Regional boards. These local boards are staffed by volunteers with a background in agriculture, natural resources, education, or government agencies. They are committed to promoting the science and professional standards associated with all aspects of crop production.

Becoming a CCA

Over 13,000 agricultural professionals have successfully gone through certification in North America. The CCA program is a voluntary process for those who wish to demonstrate, through testing and continuing education, that their experience, education and ethics bring a superior value for their clients. Any public, commercial or independent agronomist, who advises farmers and can meet the rigorous standards of the program, is encouraged to participate.

The fundamental standards are the same, regardless of where the CCA lives. The basic requirements include:

- have up to four years crop advising experience depending on educational background (university degree and two years' experience, college diploma plus three years' experience, high school and four years' experience)
- document their education and crop advising experience with supporting client references and transcripts
- pass two exams: (1) a comprehensive national exam and (2) a local state exam. The testing covers four competency areas:
    - soil fertility,
    - integrated pest management,
    - crop production, and
    - soil and water management
- sign and agree to uphold the CCA Code of Ethics

Upon completion of these requirements, the candidate will be invited to join the CCA program. The successful candidates are recognized to have a level of expertise and achievement that is documented to be superior to those that are not certified. Once certified, the registrant must complete 40 hours of approved continuing education every two years in the four competency areas.

In recognition of the success of the CCA program in North America, a group of public and private agencies has successfully launched the India Certified Crop Adviser Program. Supported by organizations such as the Gates Foundation and various international organizations, the India CCA program aims to develop the professional skills of the agronomists who advise farmers.

Recent California CCA Experience

Although CCA's are tested and certified in four areas (soil fertility, integrated pest management, crop production, and soil & water management), one of the most visible activities in California has been in the area of nutrient management.

The contribution of an independent agronomic professional to develop nutrient management plans has been recognized by regulatory agencies in California. One example is the Central Valley Regional Water Quality Control Board: General Order on Waste Discharge Requirements (WDR) for Existing Milk Cow Dairies. In this order, various parts of implementation (e.g. sampling, analysis, crop selection, nutrient budgeting) must be performed or reviewed by a "Certified Nutrient Management Specialist". The CCA credential is recognized by the Water Board to meet the requirements of this order.

Since management of organic-based nutrient sources is generally more complicated than traditional inorganic fertilizers, a special Manure Management Certification is offered by the California CCA Board. This option is offered to CCAs in good standing who wish to demonstrate superior knowledge in dealing with issues of importance to the animal and dairy industry. Special training classes are offered prior to the exam in order to review the Performance Objectives. Successful completion of this manure certificate can be used to help clients who are searching for qualified technical assistance, and also for CCA's wishing to demonstrate their high level of expertise.

Other California regulatory agencies are also recognizing the growing importance of having certified professionals making recommendations on nutrient decisions. For example, the Central Coast Regional Water Quality Control Board released a proposal in early 2010 that many farming operations be required to have a nutrient budget assembled and monitored by a certified professional (which could be a CCA). This proposal has since been revised, but the new proposal to the Board still contains a similar requirement.

In some of the states in the eastern U.S., concerns about phosphorus loss in surface runoff water have led to regulations that requires a certified professional [CCA or Technical Service Provider (TSP)] to monitor and approve all animal manure applications. Clearly this trend to using CCA's to oversee local agronomic practices is growing. This strategy allows regulatory agencies to put general guidelines in place and then allow site-specific management and appropriate flexibility be used by a professional CCA to meet the overall farm goals.

Constructing farm-scale nutrient budgets is not a simple task for anyone. It requires a thorough understanding of all potential inputs and outputs of nutrients. This understanding of fate and transport pathways needs to be then adapted to individual field-level conditions. The results from laboratory analysis and regulatory guidelines must be translated into agronomic practices that can be implemented on the farm. It requires a complicated synthesis of the "4R" stewardship concept of applying nutrients in the Right Source, Right Rate, Right Time, and Right Place.

Additional training will be offered in the future for CCA's to help them understand both the scientific concepts as well as the regulatory requirements they are expected to understand and to advise farmers on. A CCA will not certify a farm as being in compliance of "nutrient balance" without the proper documentation. To do otherwise would be a violation of the ethics standards and would result in the CCA being expelled from the program.

There is a clear need for a large body of certified agronomic professionals to make accurate and timely advice on managing plant nutrients. There is growing number of experienced agronomists who are demonstrating their commitment to their profession by going through process of becoming a Certified Crop Advisor. In California, this begins by obtaining information at the state CCA website: http://cacca.org/

The Value and Use of an Accredited Agronomist

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When Compliance is Complicated: Co-Management for Food Safety and Conservation In California's Central Coast Region

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Introduction

As a result of increasing pressure to demonstrate field management practices that avoid pathogen contamination of fresh produce, growers in California's Central Coast region have found themselves caught in a complicated balancing act. Produce growers report that they are increasingly caught in an untenable position – forced to choose between meeting their natural resource conservation goals and legal obligations, or meeting the food safety guidelines or requirements of their auditors and buyers. This paper presents a brief review of ways in which food safety guidelines may inadvertently discourage growers from using resource conservation practices, or place pressure on growers and/or landowners to contravene existing laws intended to protect natural resources and human health.

Background

On-farm management practices in many California Central Coast fresh produce growing operations have changed in response to increased food safety concerns following outbreaks of food-borne illness linked to fresh produce. Growers report being pressured by auditors, inspectors, and other food safety professionals to modify field level management efforts in ways that may impact food safety, conservation objectives and economic viability of the farming operation (Lowell *et al*. 2010). Specifically, growers report being told that wildlife, non-crop vegetation and water bodies pose a risk to food safety (RCD, 2009). Grower surveys also provide clear evidence that in response to pressure from auditors, inspectors and other food safety professionals some conservation practices are now being removed and/or discontinued. For example, twenty-one percent (21%) of growers surveyed in 2007-2008 reported that they had removed or abandoned conservation practices. In addition, many growers have taken steps to eliminate wildlife, vegetation, and water bodies near crops in response to pressures from auditors, inspectors, and other food safety professionals. Eighty-nine percent (89%) of all growers who responded to the 2007 survey indicated that they had adopted at least one measure to actively discourage or eliminate wildlife from cropped areas in response to expressed food safety concerns (RCD, 2007). Grower surveys and interviews from 2009 provide additional evidence. For example 28% of survey respondents stated they had installed fencing to deter wildlife, and 22% reported installing bare ground buffers between natural habitat and row crops for the same purpose (RCD, 2009).

Industry leadership and federal agencies charged with food safety oversight in fresh produce have sought strategies to address heightened concern about field level pathogen contamination of produce. In California and Arizona, USDA based marketing agreements called Leafy Green Marketing Agreements (LGMA) are administered through collaborative agreements between federal and state agencies. Signatories of the LGMA agree to adhere to specific Good Agricultural Practices (GAPs) aimed at reducing food safety risk. Numerous private inspection services administered by produce buyers and third party auditing services are also used to evaluate field level management targeting food safety concerns. Joint efforts by the U.S. Department of Agriculture (USDA) and Food and Drug Administration (FDA) are underway to craft rules to address preventative controls for pathogen contamination in fresh produce. A new rule by FDA is expected in 2011. President Obama signed the FDA Food Safety Modernization Act into law January 4, 2011. The new law is intended to strengthen FDA's ability to detect, prevent and respond to food safety problems, including food safety issues related to imported food.

Many food safety guidelines are proprietary, and direct connections between food safety guidelines and management decisions that appear to stem from food safety concerns are hard to describe. Food safety guidelines that are publically available rarely prescribe on-farm management decisions. For example, a private company audit available online[1] notes that animal tracks throughout the growing area are grounds for rejection of harvested product. The checklist directs the auditor to reject the crop, not to tell the grower what to do to address the concern. Yet growers report that they are often directed by food safety inspectors to reduce the likelihood of wildlife movement near crops by removing habitat that might encourage their presence (Beretti and Stuart 2008; RCD 2009). Food safety related management decisions that undermine conservation objectives and may be costly to the grower generate tensions in the tenuous balancing act of farming.

As growers manage farming operations they must consider a wide range of biological, legal and market forces that impact their operations. Co-management considers the implications of a management decision in multiple dimensions (Crohn and Bianchi, 2008; Lowell et al. 2010). For example, increased use of drip irrigation systems may impact food safety concerns if irrigation water is less likely to be in contact with the edible portion of a crop than when overhead systems are used. Installation of drip systems represents a cost to the grower, but may also help meet water quality objectives for discharge water by reducing volume of discharge, and perhaps allowing different nutrient management strategies (e.g., precisely placed fertigation). In the context of food safety discussions, co-management has been defined as an approach to minimize microbiological hazards associated with food production while simultaneously conserving soil, water, air, wildlife and other natural resources (Lowell *et al*. 2010).

In the Central Coast region water quality issues and conservation objectives related to endangered species and unique habitat have led to several challenges for co-management. Waterways in the central portion of the Central Coast region flow into the Monterey Bay National Marine Sanctuary, the largest marine sanctuary in the continental United States and an area of exceptional significance for wildlife and commercial fisheries. Riparian areas provide essential habitat for birds, mammals, fish (including the federally listed as Threatened steelhead trout (*Oncorhynchus mykiss*), and amphibians (including frogs, toads, snakes and salamanders). The Central Coast region is home to more than 80 species listed or proposed for listing under the U.S. Endangered Species Act (Lowell *et al*. 2010).

Growers must consider numerous existing laws at federal, state, and county levels that could come into play as they make food safety management decisions. The major categories in which actions taken to address food safety concerns are likely to lead to conflict with laws and ordinances include the following: water/wetland management; stream bank protection measures;

[1] See http://diamondproduce.com/grower/blackdog/yuma/risk%20assessment.pdf

water quality; pesticide use and protection of birds/fish/animals/plants designated endangered, threatened or otherwise protected. Organic growers may be particularly challenged as language in the National Organic Program (NOP) regulation requires that organic growers demonstrate maintenance or improvement of the natural resources of the operation, including soil and water quality, as well as support biodiversity. Recently the NOP accepted the National Organic Standards Board (NOSB) suggestion to strengthen the biodiversity conservation mandate of the NOP rule (NOSB 2009).

The following section examines examples of direct conflict as growers co-manage their operations. The first section documents legal actions or threatened actions related to food safety motivated actions, while the latter part explores areas in which future challenges are likely.

Review of Specific Cases of Co-Management Compliance Challenges

The following cases illustrate examples in which food safety motivated management actions have led to non-compliance with existing law. These cases describe violations of California Water Code sections 13267 and 13383, as well as violations of section 301 of the federal Clean Water Act, which requires a Clean Water Act section 404 permit for dredge and fill activities. All documentation for the following is publicly available through the Region III Water Quality Control Board (RWQCB).

Case 1: In mid-April of 2008 a Central Coast grower was noted to have removed wetland vegetation, filled a lake/wetland area, and tilled the area for cultivation. In March 2010 the RWQCB notified the grower that their field management actions were in violation of California Water Code and federal Clean Water Act provisions. The grower hired a consulting firm which prepared a written document to explain the food safety motivation for the management actions:

> "[redacted] *would like to reiterate its commitment to balance food safety with water quality. This project was completed to clear dense stands of willows that have historically supported rodent populations detrimental to vegetable crops. These rodents have become a grave concern for the food safety of spinach and other organically grown vegetables."*

Notes from the RWQCC file for the case state:

> *"*[redacted] *reported that the food safety people don't want to see a wetland and that they require buffers around it."*

Case 2: In May 2007 a Central Coast grower was noted to have converted approximately 20 acres of wetland/willow habitat to crop production, and to have diverted surface flow without permits. In January 2010 the RWQCB notified the grower that their field management actions were in violation of California Water Code and the federal Clean Water Act. The grower sent a written response to RWQCC which included the following statement indicating that actions were taken in direct response to food safety concerns:

> *"A ditch was installed from the outlet of the West Culvert to take water around production fields to the dedicated drainage area. These actions were completed in an effort to mitigate potential bacterial contamination from entering the farm ground from adjacent range land."*

Case 3: Unpermitted grading of a streambed and riparian vegetation at a third site were similarly cited. These activities require a Streambed Alteration Agreement (SAA), issued by California Department of Fish and Game (CDFG), which the grower had not obtained at the time the work was done. A retroactive SAA was issued, but further actions led to a violation of Clean Water Act section 301 citation from the U.S. Army Corp of Engineers (ACOE). RWQCB staff state that the grower has cited food safety concerns as an important motivating factor for the actions described in the violation notice.

Other compliance tensions focus on wildlife management. For example, in a Central Coast case, a landowner with deer grazing in a lettuce crop requested depredation permits. After granting repeated depredation permits, and removal of 40 deer, the Fish and Wildlife Service advised the land owner to use other best management practices (e.g., fencing) to address the problem. The land owner threatened to sue CDFG for failure to authorize depredation permits as this did not allow him to manage food safety risk as he felt he must.

Management of non-agricultural lands for food safety concerns may also be problematic. For instance, in a March 2007 letter a Caltrans Director sent a letter to the Agriculture Commissioner and Farm Bureaus noting:

> *"Since the E. coli bacteria outbreak this past year, the Department of Transportation (Caltrans) has observed an increased number of property owners and ranchers performing vegetation management measures where the State Right-of-Way abuts private property. These efforts include mechanical, manual, and chemical weed and brush control which may be in direct violation of Caltrans vegetation management policies, environmental law and permits obtained by Caltrans from other regulatory agencies."*

Conflicting Priorities Suggest Future Co-management Complexity

Calls for more aggressive protection of endangered species have already created additional challenges for food safety co-management. For example, in July 2002 Washington Toxic Coalition sued the EPA in the U.S. District Court for the Western District of Washington, claiming that EPA had failed to protect federally listed salmonids, and further had failed to adequately consult with National Marine Fisheries Services (NMFS) concerning the effects of pesticides on federally listed salmonids, their habitat and their Critical Habitat. In the ensuing eight years a series of additional law suits and injunctions have moved through EPA, NMFS and the courts. In response to criticism (including the above described lawsuit) that EPA has not been appropriately responsive to risk to endangered species in pesticide registration and labeling responsibilities (as mandated by Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)), an initiative of the Endangered Species Protection Program was launched to tie pesticide labels to Endangered Species Bulletins in an online database. The intent of the Endangered Species Bulletins Live is to strengthen endangered species protection by adding language to pesticide labels that requires users be aware of endangered species in the application area, and that they take appropriate measures to protect these species. Given the language requiring or strongly encouraging vegetative buffers that has emerged from the NMFS Biological Opinions that resulted from the Washington Toxic Coalition vs. EPA lawsuit, and existing pesticide labels (e.g. see buffer requirements on Capture 2EC-CAL EPA Reg. No. 279-3114 and Dimilin 2L EPA Reg. No. 400-461), it is reasonable to assume that language in the Codes and Limitations section of the Endangered Species Bulletins will direct growers to maintain exactly the kinds of non-crop vegetation that growers are reporting pressure to remove in response to food safety concerns.

Riparian habitat management is likely to be another area of increased scrutiny in assessment of the impact of on-farm management for food safety. Riparian habitat is essential for many wildlife species, as well as for water quality protection. The unique qualities of riparian zones may make them habitat for a particularly diverse population of wildlife (Naiman *et al.* 1993). Many creeks and rivers within the Central Coast region, including the Salinas River are designated as Critical Habitat for the steelhead, which is federally listed as Threatened (NMFS 2005). Riparian vegetation is critical to maintain adequate water quality and habitat features for this endangered species (Thompson *et al.* 2006; Rundio and Lindley 2008). The riparian corridors along Central Coast rivers and streams provide critical habitat connectivity for large and small mammals, southern steelhead and neotropical migratory birds (Penrod *et al.* 2001). As pressure mounts to support conservation mandates, lawsuits like the one filed by the Washington Toxin Coalition force the tensions among different co-management objectives into conflict.

Water quality protection is another area in which considerable tension between management objectives exists. A recent challenge has emerged as the advocacy group Monterey Coastkeeper filed suit against Monterey County Water Resources Agency (MCWRA) alleging MCWRA is polluting the waters of the Central Coast and the United States by failing to regulate agricultural operation discharge waters with pollutants, such as pesticides and nitrates in excess of protective standards (Abraham 2010). The RWQCB is engaged in a series of discussions with local growers to address discharge water quality standards through an Agricultural Waiver, which guides grower compliance with water quality objectives. The value of vegetated treatment systems and engineered water bodies to address water quality concerns in irrigated row crops in Central Coast fresh produce growing operations remains hotly contested, as these systems are typically more effective when longer retention time and lower pollutant concentrations of discharge water are present (Long *et al.* 2010). With pressure from food safety inspectors making vegetated treatment systems and riparian habitat less appealing, and regulators and advocacy groups demanding effective mitigation, growers find themselves faced with mounting pressure to respond, but few options that all agree will address water quality concerns in their operations.

Ironically, some of the food safety measures reported by growers, for example removal of non-crop vegetation, may increase the likelihood of harmful impacts on human health in other dimensions. For example, hedgerows may effectively mitigate pesticide drift (NMFS, 2008), which is responsible for approximately 31% of acute pesticide exposures documented between 1998 and 2002 nationwide (Alarcon *et al.* 2005).

Building Effective Dialogue in Co-Management

While it is not the scope of the work presented here, it is important to note that many of the most pressing challenges to co-management relate to liability and public risk perception of food safety issues. Addressing the impact of these factors on co-management will require more than new regulations and increasing scrutiny of on farm operations.

Robust input from a variety of stakeholders, respectful dialogue to explore different positions and underlying interests, and detailed tracking of the impact of on-farm management decisions in all dimensions of food safety, conservation and economic viability of farming operations are essential. It is likely that both regulatory and industry guidelines will be adjusted in an iterative process as unintended consequences of management decisions are noted and corrected.

Literature Cited

Abraham, K. 2010. Monterey Coastkeeper sues Water Resources Agency over farming pollution. Monterey County Weekly, Oct. 21, 2010.

Alarcon et al., 2005. Acute Illnesses Associated with Pesticide Exposure at Schools. *JAMA*, 294:455-465.

Beretti, M. and D. Stuart. 2008. Food Safety and Environmental Quality Impose Conflicting Demands on Central Coast Growers. *California Agriculture* 62(2):68-73.

Crohn, D. and M. Bianchi. 2008. Research Priorities for Coordinating Management of Food Safety and Water Quality. *Journal of Environmental Quality,* 37(4):1411-1418.

Long, R. F., B. R. Hanson, A.E. Fulton, D.P. Weston. 2010. Mitigation techniques reduce sediment in runoff from furrow-irrigated cropland. *California Agriculture*, 64(3):135-140.

Lowell, K., J. Langholz, and D. Stuart. 2010. *Safe and Sustainable: Co-Managing for Food Safety and Ecological Health in California's Central Coast Region.* San Francisco, CA. and Washington, D.C: The Nature Conservancy of California and the Georgetown University Produce Safety Project.

Naiman, R.J., H. Decamps, M. Pollock. 1993. The Role of Riparian Corridors in Maintaining Regional Biodiversity. *Ecological Applications*, 3(2):209-212.

NMFS, 2005. Designation of critical habitat for 7 salmon and steelhead ESUs in California. http://swr.nmfs.noaa.gov/chd/Final_CHD_4b2_Report-Aug_05-part_1.pdf

NOSB, 2009. Formal Recommendation of the National Organic Standards Board (NOSB) to the National Organic Program (NOP), Biodiversity Conservation, May 6, 2009. Retrieved Dec. 15, 2010: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5078051&acct=nosb

Penrod, K, R. Hunter, M. Marrifield. 2001. Missing Linkages: Restoring Connectivity in the California Landscape, Conference Proceedings. Co-sponsored by California Wilderness Coalition, The Nature Conservancy, U.S. Geological Service, Center for Reproduction of Endangered Species, and California State Parks.

Resource Conservation District. 2007. A Grower Survey: Reconciling Food Safety and Environmental Protection. Salinas, CA: Resource Conservation District of Monterey County.

Resource Conservation District. 2009. Challenges to Co-Management for Food Safety and Environmental Protection: A Grower Survey. Salinas, CA: Resource Conservation District of Monterey County.

Rundio, D.E. and S.T. Lindley. 2008. Seasonal Patterns of Terrestrial and Aquatic Prey Abundance and Use by Oncorhynchus mykiss in a California Coastal Basin with a Mediterranean Climate.*Transactions of the American Fisheries Society* 137:467–480, 2008.

Thompson, L.C., J.L. Voss, R. E. Larsen, W.D. Tietje, R.A. Cooper and P.B. Moyle. 2006. Role of hardwood in forming habitat for southern California steelhead. Presented at Sixth California Oak Symposium: Today's Challenges, Tomorrow's Opportunities, October 9-12, 2006. Rohnert Park, CA.

American Society of Agronomy
California Chapter

Session V
Dairy Issues

Session Chairs:
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Volatile Organic Compounds Emitted from Dairy Silages and other Feeds

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Abstract

Ground-level ozone formation continues to be a critical problem in the United States. The problem is especially severe in California, generally, and Central California's San Joaquin Valley (SJV), specifically. Dairies are one of the major sources of volatile organic compounds (VOCs) in SJV and have recently attracted considerable attention from the regulatory agencies. A number of recently conducted studies have reported actual emissions data from different dairy sources. However, there is currently limited data available for feed storage and silage piles, which are potentially significant contributors to ozone formation. The impact of different VOCs on ozone formation varies significantly from one species to another. Comprehensive measurements of VOC emissions are required to fully characterize and include all the important contributors to atmospheric reactivity. Therefore, the identification of emitted VOCs is needed to properly assess the wide spectrum of chemicals involved in ozone formation. This research study aims to identify and quantify the VOCs emitted from various silages and other feed sources. We have conducted experiments in an environmental chamber using large representative samples under controlled conditions. Over eighty VOCs were identified and quantified from corn, alfalfa, and cereal silages, total mixed rations, almond shells, and almond hulls using gas chromatography-mass spectrometry (GC/MS). Emissions of aldehyde compounds and acetone were measured using high performance liquid chromatography. The results revealed high fluxes of alcohols and other oxygenated species. Lower, but perhaps comparably significant, concentrations of highly reactive alkenes and aldehydes were also detected. Additional quantitation and monitoring of these emissions are essential for assessment of and response to the specific needs of the regional air quality in the SJV.

Introduction

Tropospheric ozone is one of the most important pollutants throughout the United States. Currently, higher ozone levels are found not only in densely populated areas and areas with intense agricultural operations, but also in remote areas. The United States Climate Change Science Program and the Subcommittee on Global Change Research have recently reported that over the past 50 years the ozone at the land surface has risen in rural areas of the United States, and is forecast to continue to increase during the next 50 years (U.S. Climate Change Science Program, 2008).

The Central California's San Joaquin Valley (SJV) has long suffered from some of the worst air pollution in United States, in general, and high ozone levels in particular. Ground level ozone formation is caused by the gas-phase reaction of emitted VOCs and oxides of nitrogen (NOx) in the presence of sunlight. The United States Environmental Protection Agency (EPA) has identified the SJV as a "severe non-attainment" area based on the federal 8-hour ozone standard. In March of 2008 the EPA adopted a new 8-hour ozone standard of 0.075 ppm (US

EPA, 2008). In order to attain this new standard for agriculturally intensive regions, the reduction of agricultural emissions of VOCs and NOx is essential.

Considerable effort at ozone reduction has been attempted in the past few decades by reducing the total mass of VOC emissions (US EPA, 2008). However, impacts of various VOCs on ozone formation differ significantly from one species to another. This makes the determination of individual VOCs crucial for the assessment of ozone reduction strategies. In particular, non-traditional VOC control strategies take into account the pronounced differences in "reactivities" of VOCs (Carter et al., 1995), and therefore further provide the means for additional ozone reduction, which could supplement mass-based control approaches. Additionally, VOC reductions have been more effective in reducing ozone in dense urban areas where, due to higher NOx levels, VOCs are the limiting factor in ozone formation. Away from dense urban areas, NOx are limiting, and the natural background of VOCs (from soils, grasses and trees) can make anthropogenic VOCs less dominant. Based on current models of the SJV air basin, even complete elimination of all sources of all types of anthropogenic VOCs would not achieve attainment of the ozone standard; in fact, it would only produce modest improvement. NOx reductions are paramount but, nevertheless, an increase in VOCs, especially the more reactive ones, would necessitate even greater NOx reductions.

Although the vast majority of ozone precursors' sources are well characterized, and their control has proven effective at reducing urban ozone (ARB, 2005, Kumar and Viden, 2007, EPA, 2008), data on dairy emissions remain sparse. Dairies are believed to be one of the largest sources of VOCs and their high concentration in the SJV is of particular concern (CARB, 2006). To make matters worse, the combination of extensive and intensive agriculture, stagnant air and low wind speeds coupled with high summer air temperatures, high summer levels of solar irradiation and cloudless skies provide the optimal conditions for ozone formation in the SJV. Therefore, evaluation and understanding of emission sources, speciation of a wide range of dairy- and agricultural-related compounds and assessment of their reactivities are critical.

Several research efforts have been undertaken in the past few years to better quantify emissions from dairies and agricultural sources.

A total of 113 compounds were identified at the Washington State University Knott Dairy Farm (Filipy et al, 2006) using GC/MS, sorbent tubes, and cryogenic traps techniques. The wide range of VOCs included alcohols in which ethanol was dominant, aldehydes, ketones, esters, ethers, sulfides, carbonyls, aromatics, and other hydrocarbons. VOC emissions from dairy cows and their waste at various stages of the lactation cycle were measured with a proton-transfer-reaction mass spectrometer (PTR-MS) using a facility at the University of California, Davis (Shaw et al., 2007). The measurements of alcohols, VFAs, phenols, and methane (CH_4) emitted from non-lactating and lactating dairy cows and their manure under controlled conditions were reported by Sun et al. (2008).

Ngwabie et al. (2008) reported chemical ionization mass spectrometry and photo-acoustic spectroscopy measurements of mixing ratios of VOCs over a two week measurement period in a large cowshed in Mariensee, Germany. Numerous VOCs were detected with alcohols (ethanol, methanol, C3–C8 alcohols) being dominant, followed by acetic acid and acetaldehyde, and included ketones, amines, sulfides, aromatic compounds, and VFAs. These results indicated that animal husbandry VOC emissions are dominated by oxygenated compounds.

Alanis et al (2008) quantified emissions of six VFAs from non-enteric sources at a small dairy located on the campus of California State University Fresno. Both animal feed and animal waste were found to be major sources of VFAs, with acetic acid contributing 70–90% of emissions from the sources tested. Measured total acid fluxes during the spring (with an average temperature of 20^{o} C) were 1.8± 0.01, 1.06 ± 0.08, (1.3 ± 0.5) × 10^{-2}, (1.7± 0.2) × 10^{-2} and (1.2 ± 0.5) × 10^{-2} gm^{-2} h^{-1} from silage, total mixed rations, flushing lane, open lot and lagoon sources, respectively with silage being the highest contributor. These data indicated high fluxes of VFAs from dairy facilities.

Recently reported studies provided improved information regarding VOC emissions from dairy facilities in general and animal waste in particular. However, while fermented cattle feed (silage) could arguably be one of the largest, and perhaps the largest, sources of dairy-related VOCs, currently there is no experimental data available on the identification and characterization of VOC emissions from silage and other feed sources. We have utilized a combination of GC/MS and high performance liquid chromatography (HPLC) with specific objectives to: (1) identify gaseous compounds emitted from different types of silage and other feed sources in order to better understand their contribution to ozone formation; (2) quantify emitted VOCs concentration and compare different silage types across the dairy; (3) measure concentration of aldehydes and ketones emitted from silages.

Reported experiments were conducted under controlled conditions, which further allow comparison of different types of typical dairy silage, and other feed sources and eliminate the influence of ambient conditions.

Materials and Methods

Silage and other feed samples were collected from commercial dairy located approximately 20 miles northwest from campus of University of California at Davis. This is a typical large size Californian dairy, representative of most western dairy operations. In this relatively new and modern facility, approximately 3000 cows are housed in freestall naturally ventilated barns with open walls. Silage piles are used as forage in dairy rations; placed aside and near other feed storage structures. The layout of these structures allows forming a feeding center.

The feed (total mixed ration-TMR) is a mixture of various components formulated to provide the optimum amount of energy and nutrition to the animals at the dairy. Silage is the largest component of the TMR. Typically, there are few different forage piles located at the dairy. Except for the vertical open-face, silage piles are covered with black plastic sheet and sealed along the sides. Tires are used for holding plastic tightly against the top surface of the pile. This helps to prevent silage spoilage, due to air exposure, and reduces emissions.

Typically, 6-12 inches of forage are removed from the face of the pile daily leaving this open part of the pile exposed to ambient air. All forage samples (corn, alfalfa, and cereal silages) within the dairy were collected early in the morning, right after a new portion of silage was removed. High moisture ground corn pile was not covered and samples were also collected immediately after new portion was removed for the TMR preparation. Other piles of feedstuff (almond hulls and almond shells) were covered for sun and rain protection (roof only, no walls structure) and their samples were collected in a similar manner.

Various feed components are loaded into a large truck where they are mechanically mixed and delivered to the animals. This operation normally takes place twice each day. The TMR samples were collected as soon as it was delivered to the animals. Large plastic bags (doubled to avoid emissions leakage) were tightly closed and immediately transported to campus.

Experiments were conducted in an Environmental Chamber (4.4m x 2.8m x 10.5m) at the Department of Animal Sciences, University of California at Davis. Background and inlet air samples were collected throughout all experiments.

Approximately 40-70 kg of silage or other feed sample were placed in large round shape bin (diameter 1.92 m) located in the center of the chamber and spread to a depth of approximately 30 cm. Chamber door was closed and sealed. All major experiments were conducted in duplicates.

Multiple air samples from the chamber outlet port were collected using 6 L SUMMA ® passivated stainless steel canisters from two manufactures: TO-Cans from Restek (110 Benner Circle, Ballefonte, PA) and Model S6L-G AeroSphere sampling canisters from LabCommerce Inc. (San Jose, CA). Canister sampling could be performed in two modes: either grab or time integrated sampling (up to 24 hours). Sampling procedures, canisters cleaning and preparation were performed according recommendations of EPA method TO-15 for the determination of toxic organic compounds through analysis of ambient air samples collected in specially-prepared canisters which are further analyzed by GC/MS (US EPA, TO-15 method) and the Laboratory Standard Operating procedures for ambient air analysis used by the California Air Resources Board (CARB, SOP MLD 059).

Results and Discussion

A total of 24 compounds were identified and quantified from silage and TMR emissions. These included 6 alcohols, 5 VFAs, and 13 carboxylic acids esters. Alcohol emissions from all silages and TMR were the dominant VOCs, with ethanol concentrations being the highest among all emitted alcohol compounds. The highest concentrations of ethanol and propanol were detected from corn silage. Significant concentration of 2-butanol was also detected from corn silage. In addition, low concentration of isopentyl alcohol was measured from corn and cereal silages. Emission fluxes of hexanol were detected from all silage samples at relatively small concentrations and not quantified. Corn silage was found to emit the highest concentration of alcohols.

Volatile fatty acids were identified as the second most abundant group of compounds emitted from silages and TMR, with acetic acid having the highest concentration within VFA emissions. High concentration of acetic acid observed in our experiments could be correlated to its presence (up to several percent by mass) in silage (Danner et al., 2003, Kung and Shaver, 2001). Propionic, isobutyric, butyric, and isovaleric acid emissions were also detected and quantified from the alfalfa silage and TMR. These findings are consistent with recently reported data on the evaluation of non-enteric emission fluxes of VFAs from five different locations including silage and TMR (Alanis et al., 2008). Similar to our results, the emissions of acetic acid were found to be higher (1-2 orders of magnitude depending on the source) from all selected sources among all measured VFAs (Alanis et al. (2008). Further, in our chamber experiments, the VFA emissions from alfalfa silage and TMR were also measured using sorbent tubes method described in details by Sun et al. (2008). In these experiments we have detected fluxes of acetic, propionic, isobutyric, butyric, isovaleric, valeric, isocaproic, caproic, and heptanoic acids. It is important to underline that despite the relatively high concentrations of emitted VFAs from dairy silages found in this report and study conducted by Alanis et al. (2008), these compounds are known to have insignificant effect on ozone formation (Carter, 1994).

A wide variety of carboxylic acids esters have been identified and quantified in addition to alcohols and VFAs emitted from silages and TMR. The emitted propyl acetate, propyl propionate, as well as ethyl, propyl, and butyl esters of butyric acid had the highest concentrations for corn silage. The highest concentration of ethyl acetate was detected from cereal silage. The composition and concentrations of identified emitted esters varied significantly among tested silage and TMR samples. Corn silage was found to emit the widest range and highest concentrations (except for ethyl acetate) of carboxylic acids esters.

Emission of only several VFAs and propyl propionate was detected from dry food components (almond hulls and almond shells), with their concentrations being below the quantification limit.

The results show that the majority of VOCs identified in the environmental chamber experiments were oxygenated compounds with alcohols being the major contributors. Total concentration of alcohols was found to vary in the range of 500-600 ppb from the TMR, alfalfa silage, and high moisture ground corn to approximately 1.7 and 2 ppm from corn and cereal silages, respectively. Among alcohols, ethanol was the most abundant throughout measurements of all silages and TMR. Besides ethanol, significant concentrations of propanol and other isomers of C3-C4 alcohols were also detected with the highest concentration emitted from corn silage. Ethanol is expected to be a dominant VOC compound since it is produced by yeast fermentation of the plant material as part of ensiling process. The combined alcohols (excluding methanol) accounted for over 80% of the total VOCs emissions measured by the canisters analyses, with the ethanol concentration alone exceeding 70% and 90% of total alcohols emissions for silages, TMR and high moisture ground corn, respectively. The ethanol emissions from cereal silage were determined to be the highest, followed by emissions from corn and alfalfa silages. However, the variability in emissions of alcohols in general and ethanol emissions in particular could vary significantly due to number of factors. In general, silages made from grass and winter grown cereals with lower carbohydrate content are expected to produce less ethanol than corn and grain silages. Furthermore, silage preparation methods, different additives, management style, climate, and ambient conditions could contribute to the variability in emissions.

In addition, the density of silage piles could also play an important role. The plant material during silage production is compressed to the point where no oxygen is present and anaerobic conditions are established that promote the growth of autochthonous lactic acid bacteria (Neureiter et al., 2005). The microbial conversion of free soluble carbohydrates into lactic acid and the resulting decrease in pH prevents the growth of undesirable microorganisms. In case of incomplete compression, the amount of oxygen could be sufficient for yeast and ferment carbohydrates to ethanol. This could be an indication of poor quality of silage.

Therefore, our experiments have demonstrated that levels of alcohol emissions from different silage types vary significantly and determine total VOC emissions.

Since silage is typically the largest component of TMR, significant but lower ethanol fluxes were detected from TMR. Alcohols are very volatile and rapidly vaporize during preparation and distribution of TMR. While the alcohols and other VOC emissions are lower from the TMR compared with silage, the feed (TMR) typically spread over a much larger area than the silage pile face. Thus, because of the larger surface area the potential for emissions from TMR could be greater than from silage.

Conclusions

This research has demonstrated the diversity of VOCs emitted from various types of silages and other feed sources. The measurements indicated that open-face silage piles are likely a significant source of VOCs in California dairies. The bulk of emitted compounds identified here are oxygenated VOCs in which alcohols are dominant, and known to have a small impact on ozone formation. However, emissions of alkenes, alkynes, diene compounds, and aldehydes from silage, which were identified and quantified here, could make a significant contribution to ozone formation. The atmospheric implications of these findings may include effects on the local air quality in agricultural areas. Comprehensive measurements of fluxes of a suite of oxygenated VOC emitted from assorted dairy feed sources are needed to assess their importance in regional chemistry.

References

References are available from the corresponding author upon request.

Study on Harvested Crop Residue: Sampling Protocol for Nutrients

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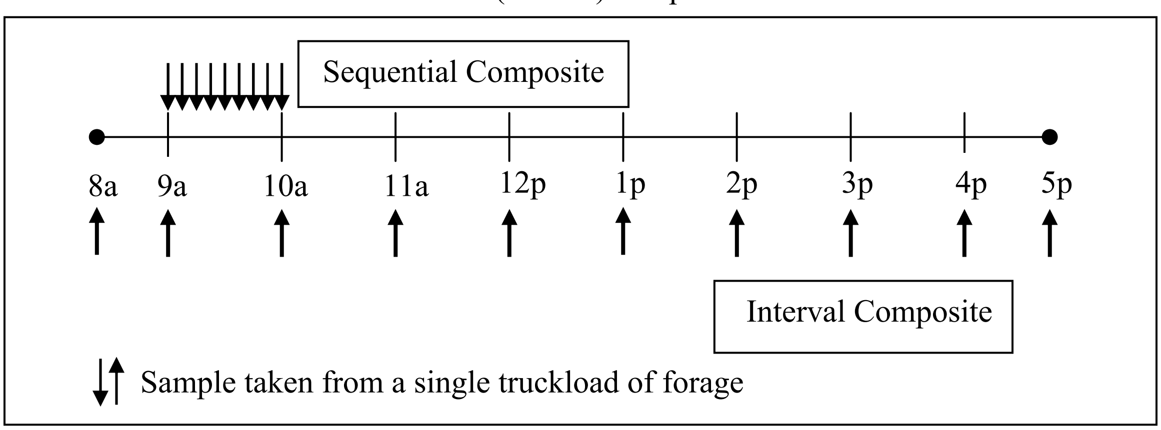
The Dairy General Order requires dairy operators to document total weight of nutrients removed from fields where manure is applied. A detailed protocol requires sub-sampling (n=8) from each 40 acres, with additional composites made to represent morning and afternoon harvest periods for dry matter (DM). Analysis of forage DM forms the basis for all nutrient removal calculations. A single composite sample for each field is then prepared for nutrient analyses. Field observations indicated the detailed sampling protocol was not generally followed at dairies.

The objective of this study was to determine if differences exist in calculating DM removal based on various intensities of sub-sample and composite collection. Weights (TL) were obtained and samples collected for each truckload of forage harvested on a single corn field at three dairies. Truckloads were sampled by taking four grab samples across the pile of forage after unloading, but before being pushed up into the silage structure. Each sample was sealed in a plastic bag and placed on ice. Dry matter was determined by sub-sampling and drying 25-40 g, in triplicate, in a 55℃ oven for 24 hours, then weighing the dry residual. DM is dry weight divided by wet weight. Actual field DM removal was determined by summing TL*DM for all samples from the field.

Field DM removal totals were calculated using two composite sampling methods (sequence and interval). Sequence values are the average of sample DM within an hour of harvest; for example, forages from trucks that unloaded between 9a and 10a (see Figure 1). Interval values are the average of every 10th sample collected, for example, forage that was unloaded at 9a, 10a, 11a, etc.

Figure 1. Example of truckload samples taken to create Sequential (top) and Interval (bottom) composites.



We found that taking a single sample of forage to estimate DM removal of an entire field yielded results that varied greatly from the actual DM removed. Using any one individual sample to estimate DM removal could underestimate harvested forage by 21.5% or overestimate forage removal by 20.4%. Sequential composites were less varied, and interval samples were the least varied of all methods tested (see Table 1).

Table 1. Differences between estimated field DM removal and actual field DM removal based on method of sampling on one cooperator dairy.

	Individual	**Sequential**	**Interval**
% difference	-21.5 to + 20.4	-5.14% to + 5.15	-2.71% to + 2.40
DM difference (lbs)	± 135,000	± 33,000	± 16,500

Determining accurate DM removal for harvested fields has many implications, including: cost of harvesting forage, maintaining accurate feed inventory as well as regulatory compliance. **Through more intense sampling, it was found that under- and overestimations were reduced. Interval samples across all dairies were ± 3% of actual DM harvested.**

Reference Material:

Waste Discharge Requirements General Order for Existing Milk Cow Dairies, Order No. R5-2007-0035:

- http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2007-0035.pdf

Currently approved sampling methods:

- http://www.waterboards.ca.gov/centralvalley/water_issues/dairies/general_order_guidance/sampling_analysis/sampling_and_analysis_21feb08.pdf
- http://www.cdqa.org/docs/Sampling_Forage_Plant_Tissue_Protocol-draft_2-25DM.doc

Use of Linear Move/Center Pivots with Manure Water

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Report Card on Nutrient and Waste Management Plan Submissions: How they Affect Management in the Field

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Adoption of Nutrient Management:Conservation Tillage and Manure Application Technology in the Dairy Industry

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Laboratory Results from the RWQCB Monitoring Requirements on Dairy Facilities

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Environmental Quality

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Postharvest Fumigation of Specialty Crops

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Abstract

Specialty crop industries are facing, with increasing frequency, environmental and pest-related food safety requirements that are fundamentally difficult to balance. This report describes critical research foci of the crop protection and quality unit of the USDA-ARS-SJVASC and lists experimental resource used in the development of postharvest chamber fumigations as phytosanitary treatments for insect control in specialty crops.

Introduction

Postharvest chamber fumigation is a critical element of the ~$18 billion/yr. CA specialty crop industry, as it provides a biological safeguard against pests and, in many scenarios, is the only available tool for government and industry to guarantee pest-free security and food safety. Failure to disinfest specialty crops in trade and marketing channels can result in insect- and microbial-derived damage with severe consequences to economic profitability and consumer health. Methyl bromide (MB) quickly penetrates commodity loads and has, in general, nondiscriminating efficacy against insect pests (Bond, 1984). MB has been used successfully for disinfestations over the last 4 decades; in fact, its routine use has left industry with infrastructural capabilities that are almost exclusively geared toward chamber fumigations. The elimination of MB use in an agricultural capacity, via international legislation under the Montreal Protocol, has created a myriad of challenges for regulatory, agricultural, and industrial bodies involved in postharvest commodity protection. The balancing/melding of human and environmental health concerns with agriculture and industrial requirements to develop and utilize functional and economical alternatives to MB, requires specific analyses for each applied scenario where MB has to be replaced or contemporary infrastructure has to be retrofitted accommodate safe usage. The expeditious development of MB alternatives and low-emission technology for chamber fumigations will enable U.S. to continue fumigating specialty crops, at least until effective non-chemical alternative treatments are broadly available and universally excepted in domestic and international markets.

MB use is still permitted for postharvest applications involving dried fruit and nuts where technically or economically feasible replacements are missing. California produces nearly all of the dried fruit and nuts in the US, each year resulting in >2,000,000 metric tons of commodity valued at ~$3 billion that needs to be disinfested of field pests and storage pests in processed products amenable to reinfestation and microbial colonization. Critical use exemptions (CUEs), encompassing ~700 metric tons/yr. of MB, have been granted for this purpose to treat dried plums, raisins, walnuts, figs, and a several other durable commodities with export value. However, CUEs in this context are expected to expire by 2013. Thus, scientists at SJVASC work with the California dried fruit and nut industry, which needs to rapidly develop technically and economically feasible methods for controlling stored product insect pests and ensuring food safety.

Quarantine and pre-shipment (QPS) uses of MB are also permitted for many specialty crops, particularly those intended for foreign markets. At any time, importing countries can confront industry with quality, quarantine, and residue requirements with the potential to terminate trade; a survey of economically significant export commodity/market combinations that require fumigation in QPS capacities, estimates 6 billion dollars is jeopardized if the QPS use of MB is disallowed. Effective MB alternatives for QPS use are being designed and tested at SJVASC to meet the internationally established level of Probit 9 security (Finney, 1971) for the specific purpose of overcoming consequential insect-related trade barriers.

If postharvest QPS MB allowances are to continue, then measures must be taken in concert with the phase-out to reduce their contribution to the global annual atmospheric input of MB, which is currently $< 5\%$. Nearly all specialty crops, are fumigated in chambers that release spent fumigants to the atmosphere, where they are then considered pollutants. In light of domestic and international regulatory pressure to limit fumigant emissions, immediate research is needed regarding the methodology required to keep fumigants out of the atmosphere following postharvest chamber fumigation; the California specialty crop industry recognizes that low-emission fumigations will be an integral part of conducting future business. Currently, there is no economically viable option to avoid or offset costs of fumigant emissions compliance. Therefore, regulations could seriously impact the profitability of California specialty crops. Scientists at SJVASC, as part of a national collaborative effort, develop commercially viable, cost efficient and effective processes to contain, destroy, or recapture/reuse methyl bromide and alternative fumigants following their use. The outcome of this research will be a reduction in unintended impacts of air-quality regulation on California specialty crop productivity, market retention, and trade expansion.

Insectary

The insectary at SJVASC is categorized as an ACL-2 facility (USDAa, 2009). It is an isolated building with dedicated electrical, plumbing, and mechanical services. The insectary has both primary and secondary barriers, rigorous disposal methods, and limited access personnel. Currently, the facility rears 17 species of pestiferous arthropods on meridic diets on a full-time basis. Included are 7 lepidopterous species and 10 species of Coleoptera. Other species are collected and established in the laboratory as required by research projects.

Fumigation facility

The fumigation facility has two controlled temperature rooms containing thirty $1ft^3$ chambers, all of which are equipped with fans, pressure regulators, and centralized exhaust aeration systems (USDAb, 2009). In addition, there are three 9 ft^3, two 133 ft^3, and a 500 ft^3 chambers that are outfitted with temperature and pressure modulators, as well as, removable fumigant adsorption beds (Leesch, 2000). The fumigation facility is also equipped with modern analytical equipment that includes six gas chromatographs customized for fumigant analysis. In addition, on-site SJVASC collaborators possess all necessary equipment to measure standard fruit quality parameters, such as firmness, color, soluble solids and acidity.

Literature Cited

Bond, E.J. manual of fumigation for insect control; FAO Agricultural Studies No. 79; FAO Plant Production and Protection Series No. 20, 1984

Finney, D.J. Probit Analysis; 3rd ed.; Cambridge Univ. Press: 1971
Leesch, J.G., G.F. Knapp and B.E. Mackey. 2000. Methyl bromide adsorption on activated carbon to control emissions from commodity fumigations. J. Stored Prod. Res. 36, 65-74.
USDA 2009a http://www.ars.usda.gov//Main/site_main.htm?docid=18134
USDA 2009b http://www.ars.usda.gov/Main/docs.htm?docid=18577

Pesticides and Surface Water: Are we making progress?

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Coalition Effort Leads to Progress

Since initiating water and sediment quality monitoring in 2004, the East San Joaquin Water Quality Coalition (ESJWQC or Coalition) has found numerous waterways where farm inputs are believed to have caused exceedances of State water quality goals. In winter 2008-09, the Coalition launched an aggressive effort to notify its member farmers in targeted watersheds about those problems and encourage adoption of practices that limit impacts of farm inputs on water quality.

This effort involved the Coalition staff meeting individually with farmers with irrigated land adjacent to three priority waterways in the Coalition region. During the visits, information was gathered on existing farming practices used on the fields next to the waterway. Discussions also covered practices to prevent future movement of farm inputs from fields into adjacent waterways.

Coalition water and sediment quality sampling from summer and fall 2009 in the three watersheds with focused outreach showed no exceedances of water quality standards except for a sample from one waterway which showed an exceedance of chlorpyrifos. Later investigation found that the insecticide was applied by a farmer who is in a separate Water Board program and was not informed of the Coalition's effort.

Two out of the three priority waterways had no exceedances of any farm inputs, in particular the targeted pesticides (chlorpyrifos, diuron and copper). While one year's results are not adequate to claim that water quality problems originating from irrigated fields are eliminated, it does provide evidence that the Coalition approach for addressing water quality can make a measurable difference to the impact of farm inputs on waterways.

Monitoring Encompasses Region

The ESJWQC region encompasses irrigated lands east of the San Joaquin River within Madera, Merced, Stanislaus, Tuolumne and Mariposa Counties and portions of Calaveras County. The Coalition started its water and sediment monitoring in 2004 in response to a regulatory program by the Central Valley Regional Water Quality Control (Water Board) called the Irrigated Lands Regulatory Program (ILRP).

All monitoring occurs under a Water Board-approved Monitoring and Reporting Program Plan (MRPP) designed to characterize agricultural discharges within the Coalition region. Since 2004, the Coalition has monitored water and sediment quality at 40 different locations within its region. Exceedances of the State's water quality goals have been recorded for a range of constituents including pesticides, metals, nutrients, physical parameters and bacteria.

A key component of the Coalition's monitoring strategy is dividing its geographic region into six zones based on hydrology, climate, soils and land use. In each zone, one site is monitored every year (Core monitoring location) and a second site is rotated every two years (Assessment monitoring location).

Following this strategy, the Coalition will eventually assess all water bodies receiving agricultural drainage in its region. The zone approach also allows the Coalition to assess water quality on a larger scale without having to maintain sampling at the same location from year to year.

Management Plan Strategy

A management plan is required by the Water Board for a waterway when Coalition sampling finds any constituent exceeding a water quality goal two times or more within a three-year period. The ESJWQC developed an overall management plan for all 27 waterways it sampled between 2004 and 2008 and set priorities for both waterways and constituents to focus on in those waterways.

In setting priorities, the Coalition is focusing first on constituents likely originating from agriculture including pesticides and sediment. The Coalition also takes into account toxicity test results from three species (water flea, algae, fathead minnow) to determine if an association exists between organism toxicity and applied chemicals.

The outreach and education strategy in each of the management plans focuses on informing growers of problems in their watershed and providing information on effective management practices. The steps taken within a management plan strategy include:

1. Evaluation of water quality data;
2. Review of pesticide use in a watershed;
3. Identify member parcels with the highest potential to affect downstream water quality;
4. Hold individual member meetings to discuss water quality issues, current management practices and additional practices that may be implemented;
5. Evaluate water quality to determine the effectiveness of newly implemented practices.

Monitoring Finds Problems

Twenty-four of the Coalition's sample sites have management plans that include up to several pesticides, with each site recording two or more exceedances of chlorpyrifos water quality goals. As a result, the initial management plans focus on chlorpyrifos, an insecticide widely used in the Coalition region due to its cost effective control of invertebrate pests on many crops, particularly almonds, walnuts and alfalfa. California Department of Pesticides (DPR) ranked chlorpyrifos 11th in its summary list of top 100 pesticides by acres treated in California in 2008. There is currently a Total Maximum Daily Load (TMDL) for chlorpyrifos in the San Joaquin River of 0.015 µg/L. After December 2010, this concentration is not to be exceeded in the river or upstream tributaries.

The Coalition recorded an increasing number of chlorpyrifos exceedances between 2004 to 2008 as monitoring site locations were expanded in scope and frequency. The weather also varied throughout the period with 2006 being an average wet year, 2008 having late spring storms and drought conditions persisting in 2007, 2008 and 2009. Each year, pest pressures varied in major crops where chlorpyrifos is commonly used and are dependent on weather, annual cropping patterns and various unknown factors.

Focused Outreach

A key component of the Coalition's management plan was to hold individual member meetings to discuss farm management practices and water quality issues. The Coalition based its decision to hold these individual interviews in priority watersheds on a number of factors. It was apparent that chlorpyrifos exceedances were continuing to occur and in fact appeared to be occurring more frequently. Also, information from management practice surveys of ESJWQC members taken in 2006 and 2007 showed that most growers were already implementing a range of management practices including those required by the CA- DPR on product labels.

In 2009, the Coalition selected three watersheds as priorities based on the following: waterway monitored for at least three consecutive years; found multiple chlorpyrifos exceedances; and represented a range of conditions in the Coalition region. The watersheds and sample sites selected were:

1. Dry Creek @ Wellsford Road (Zone 1)
2. Prairie Flower Drain @ Crows Landing Rd (Zone 2)
3. Duck Slough/Mariposa Creek @ Hwy 99 (Zone 5)

In its initial effort, the Coalition focused on members with the potential to drain directly to the three waterways. This included fields immediately adjacent to the waterway with the potential to drain during normal irrigations or winter storms. Also fields where spray drift could reach adjacent waterways.

Each member was contacted through registered mail to schedule individual interviews. Coalition representatives traveled to the member's farms and discussed downstream water quality issues, their current management practices, pest pressures and potential new practices that could be implemented.

Conditions Vary in Each Watershed

Each of the three priority watersheds was unique in the number of irrigated acres, types of crops grown and management practices used on the fields. For example, growers along Prairie Flower Drain have the highest percentage of acreage with irrigation drainage, about half the acreage along Duck Slough/Mariposa Creek has irrigation drainage and Dry Creek has less than 15% of its acreage with irrigation drainage.

The type of crop grown in each watershed tended to determine the amount of irrigation drainage. Orchard crops dominate the Dry Creek region while row and field crops are the majority in the Prairie Flower Drain watershed. Duck Slough watershed is a mixture of orchards, row and field crops.

Dry Creek Watershed (Stanislaus County)

With growers along Dry Creek, preventing spray drift was the focus of discussions. This was based on analysis of chlorpyrifos concentrations (very low) and its total use in watershed (substantial), which showed no relationship.

Duck Slough/Mariposa Creek Watershed (Merced County)

For acreages with irrigation drainage to Duck Slough/Mariposa Creek, east of Highway 99, discussions with members focused on a combination of spray drift management, control of storm drainage, allowing vegetation to grow in ditches and adding drainage basins/sediment ponds where needed.

Prairie Flower Drain @ Crows Landing (Stanislaus County)

Fields adjacent to Prairie Flower Drain with irrigation drainage were predominantly field and row crops. Landowners were encouraged to adopt management practices such as controlling the timing of pumping or draining into the waterway (following pesticide applications), allowing some vegetation growth in drainage ditches and constructing drainage basins/sediment ponds to hold field runoff.

Attention To Spray Drift Management

Because of the potential for spray drift from any field adjacent to a waterway, growers in all watersheds were encouraged to closely follow spray drift management practices including:

1. On outer two rows, shut off outside nozzles and spray inward only;
2. Spray areas close to water bodies when the wind is blowing away from them;
3. Make air blast applications when the wind is between 3-10 mph and downwind of a sensitive site.

Measuring Success

Measuring the effectiveness of Coalition efforts in reducing the impact of agricultural practices on water quality is difficult for many reasons including:

- Not all landowners along a waterway are coalition members;
- A field may be enrolled and regulated under the Regional Water Board “Dairy Program” and not contacted by the Coalition;
- Direct source and “cause and effect” of a single exceedance is often difficult if not impossible to confirm.

The Coalition represents approximately 60% of the irrigated agriculture in its region. The other 40% does not receive information from the Coalition about water quality issues, management practices or funding sources to help finance management practice implementation (although other information sources are available to landowners).

In many San Joaquin River watersheds, particularly Dry Creek and Prairie Flower Drain watersheds, considerable acreage is enrolled in the Regional Water Board’s “Dairy Program.” Landowners with fields covered by this program are not required to monitor runoff that could carry pesticides used for production of feed crops. This complicates the task of assessing the contribution of water quality impairments due to fields regulated under the Dairy Program versus fields regulated under the ILRP.

Sources Difficult to Identify

The Coalition uses numerous resources to identify potential sources of water quality impairments in a watershed including:

1. Pesticide Use Reports;
2. Crop and parcel information;
3. Upstream and temporal monitoring;
4. Grower interviews;
5. Analysis of pesticide concentrations and pounds of chemical applied to crops in a watershed.

However, it is difficult to know with certainty whether water quality issues are a result of a single pesticide application (lack of management practices) or a pest outbreak and a high amount of use (even with good management practices followed).
Even more difficult to determine are sources outside the influence of Coalition efforts. This includes:

- Nonmembers with irrigated crop land;
- Dairy operations with irrigated lands;
- Non irrigated crop land;
- Non-commercial farming areas (one- to five-acre ranchettes);
- Rural residences and septic systems;
- Other rural land uses such as industrial, rights-of-way or non-irrigated open lands.

Whether Coalition efforts can be credited with the absence of pesticide exceedances cannot be said with 100% certainty. However, the Coalition considers the significant decrease in chlorpyrifos exceedances in 2009 an important step in demonstrating the effectiveness of its management plan strategy. In addition, member feedback on this strategy has been positive and encouraging. In all cases the growers have appreciated the individual visits and are much more aware of downstream water quality concerns as a result.

The ESJWQC members are continuing efforts to ensure that water quality within the region is not impaired by sources related to agricultural production. The Coalition is a resource to its members for information on management practices, references to grant funding for installing structural management practices (i.e. sediment ponds) and updates of local water quality monitoring results. Its Annual Report provides an overview of Coalition programs and a review of past and current water monitoring results.

Pesticide Use and Residue Tolerances: Sprayed Safe Produce!

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Pesticide use and trace residues in safe, high value produce can be controversial. Sprayed and unsprayed produce can be distinguished at residue levels where safety isn't the issue! This discussion will examine the chemical side of the issue.

Farmers who accept the challenge of providing fruits and vegetables to increasingly large numbers of consumers recognize particular insects, mites, weeds, nematodes, disease-causing organisms, and vertebrates as competitors that may lower the quality and yield of their produce. Managing pests in crop protection has been a continual challenge wherever agriculture has been practiced. The ageless competition between insects and humans was described like this in a 1915 extension bulletin:

> "It is due to the fact that both men and certain insect species constantly want the same things at the same time. Its intensity owing to the vital importance to both, of the things they struggle for, and its long continuance is due to the fact that the contestants are so equally matched. We commonly think of ourselves as the lords and conquerors of nature, but insects had thoroughly mastered the world and taken full possession of it long before man began the attempt."

The widespread introduction of synthetic organic pesticides into crop protection in the 1940s allowed reduction of pest abundance and pest damage to levels that were not previously possible. Plant breeding, fertilization, irrigation, and pesticide technologies are characteristics of the world's most productive agriculture in spite of the continuing presence of pests. Since 1900 Americans spend 50% less of their income to feed themselves (Food Marketing Institute 1994). A National Academy of Sciences estimate (NRC 1991) of disposable income of a typical American family indicated that approximately 10% is used to purchase food, lower than any other country (CAST 1992). These data prompt the suggestion that a major benefit of pesticide use is an abundant supply of nutritious, affordable, flavorful produce.

California Pesticide Use in Crop Protection

Consider the extent of pesticide use in agriculture and in the 4 leading counties in particular. Pounds applied are registered by the most extensive use reporting system in the world. Year-to-year differences are relatively small and sulfur is most used.

County (rank)	Millions of Pounds of Pesticide Applied			
Year	2008	2007	2006	2005
Fresno (1)	27.5	26.0	31.8	32.1
Kern (2)	25.4	26.0	30.1	28.1
Tulare (3)	14.3	15.3	17.5	17.0
San Joaquin (4)	6.8 (7)	9.1	11.3	11.9
California Total	**161.5**	**171.9**	**189.6**	**195.2**

Gross Cash Receipts of California Agriculture, 2009

Sector	Value in Billions of Dollars
Fruits and Nuts	10.87
Livestock and Poultry	10.63
Vegetables and Melons	7.31
Field Crops	4.08
Nursery and Floriculture	3.29
California Total	**36.2**

Agricultural Productivity of Leading California Counties, 2008

County (rank)	Value in Billions of Dollars
Fresno (1)	**5.7**
grapes, almonds, poultry, milk, tomatoes	
Kern (2)	**5.0**
milk, oranges, cattle and calves, grapes, alfalfa	
Tulare (3)	**4.0**
milk, grapes, citrus, almonds and byproducts, carrots	
San Joaquin (7)	**2.1**
milk, grapes, walnuts, cherries, almonds	

Pesticide Residue Monitoring: Sprayed or Unsprayed Produce?

California's residue monitoring program is the most extensive state program in the nation. The program provides important pesticide residue data to assure a wholesome and safe food supply. Specific goals include:

1. Monitor pesticide residues in fresh produce throughout the California food supply.

2. Identify specific commodities that have a higher incidence of illegal residues.

3. Generate data requested by the Department of Pesticide Regulation's Medical Toxicology Branch for risk assessment of particular pesticides.

4. Enforcement actions to keep produce with illegal residues out of the marketplace.

The USDA Pesticide Data Program (PDP) is a national pesticide residue monitoring program. Through cooperation with State agriculture departments (see 1. above) and other Federal agencies, PDP manages the collection, analysis, data entry, and reporting of pesticide residues on agricultural commodities in the U.S. food supply, with an emphasis on those commodities highly consumed by infants and children. The California Pesticide Residue Monitoring Program is an important contributor to the PDP program based upon the regional pattern of pesticide use, the existence of sampling and advanced analytical capability, and DPR's commitment to protect human health and the environment.

Summary of California Pesticide Residue Monitoring Program, 2005-2009

Year	Samples Analyzed/ Types of Produce	Samples with Non-detected Residues	Tolerance violation[a]
2009	3,429/180	2,517/73.4%	2.4%
2008	3,483/140	2,444/70.2%	1.1%
2007	3,562/100	2,230/62.6%	1.2%
2006	3,590/90	2,280/63.5%	1.3%
2005	3,672/76	2,424/66%	0.87%
[a]Usually illegal rather than above tolerance			

PDP data continue to demonstrate the safe use of pesticides in the production of the U. S. food supply. The U.S. Department of Agriculture implemented PDP in 1991. Since then, PDP has applied their multiresidue screening to about 30 commodities in the U.S. food supply. Using a rigorous statistical approach to sampling and the most current laboratory methods, PDP has tested fresh and processed fruit and vegetables and other agricultural commodities where pesticide residue tolerances are in place.

PDP data support the implementation of the 1996 Food Quality Protection Act that directs the Secretary of Agriculture to collect pesticide residue data on foods that are highly consumed by infants and children. The U.S. Environmental Protection Agency (EPA) uses PDP data as a critical component for dietary assessments of pesticide exposure. The extensive and reliable PDP results provide realistic exposure information to the EPA assessment process. Approximately 64% of 88,034 fresh fruit and vegetable samples analyzed from 2000 to 2008 had detectable pesticide residues in the washed, edible tissues. The PDP pesticide residue data are summarized annually (http://www.ams.usda.gov/science/pdp).

So what about produce—Sprayed or unsprayed and our health? Is there a difference?

When pesticides are used in crop protection, trace chemical residues on fruits and vegetables occur at some level that may be measurable with sensitive analytical procedures (USDA 2010; Baker et al. 2002).

Pesticide residues begin to decline at application as a result of physical processes such as volatization and photolysis and biological mechanisms including plant and microbial metabolism. Residues will continue to decline during transport, storage, and home or commercial food preparation. Pesticide tolerances are used to regulate use practices. Tolerances or Maximum Residue Limits, as they are termed in international agriculture, are the maximum amounts of pesticide residue allowed by law to remain in or on a harvested crop. Tolerances represent residual pesticide in supervised field trials performed according to Good Agricultural Practices. The residue levels are well below amounts that might be harmful to consumers based upon single, multiple, or other hypothetical patterns of consumption, but they may also become a consumer concern with respect to dietary pesticide exposure (FQPA 1996).

Pesticide use in crop protection is regulated in the U. S. by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetic Act

(FFDCA) that require establishment and enforcement of pesticide residue tolerances. Very significantly the 1996 Food Quality Protection Act (FQPA) that established a health-based standard for tolerance to provide "reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information" results in the EPA conducting both aggregate and cumulative risk assessments. The risk assessment paradigm offered (NRC, 1983) and refined (NRC, 2009) by the National Research Council is a relatively transparent, evidence-based regulatory process used by the EPA to meet the requirements of FQPA. Risk assessment concerning a particular regulatory issue such as pesticide residues in fruits and vegetables includes: (1) hazard identification, (2) dose-response relationships, (3) exposure assessment, and (4) risk characterization. Pesticide residue data that represent the consumer exposure potential of fruits and vegetables are essential for the development of reliable and responsible characterization of consumer risk.

Premarket safety evaluation of chemicals utilizes a rigorous set of guidance studies to reveal the acute, short term, and chronic effects of chemicals intended for ethical use as pesticides (and pharmaceuticals). The process systematically reveals the relationship between the intrinsic toxicity of chemicals and the likelihood that exposures will produce adverse effects (toxicity). The steps are referred to as hazard identification and the determination of dose-response relationships in laboratory animals. In well designed, scientific safety evaluation studies, the identification of a chemical's potential to cause adverse effects is coupled with determination of a level or dose at which 'no-adverse-effects' have been established by scientific judgment and expert opinion. Estimates of short-term or acute dietary exposures can be determined to clarify the relationship between exposure and thresholds for adverse effects. The premarket safety evaluation process establishes a science-based foundation for assurances of the safety of pesticide use in production agriculture. Pesticide residue tolerances represent "reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information." No Observed Adverse Effect Levels of exposure (NOAELs, mg/kg) represent dosages that do not permit distinction of treated and control organisms are critical outcomes for risk assessment and risk communication.

The PDP data reveal the extent of residues resulting from pesticide use in the production of fruits and vegetables. The data document the occurrence of relatively well-studied pesticides in the total diet. Knowledge of the occurrence of residues and the supporting pesticide toxicology database contrasts sharply with the largely uncharacterized estimated half million naturally occurring chemicals ranging from low-molecular weight flavors and fragrances to macromolecular proteins and polysaccharides that also occur in our foods (Fenwick and Morgan, 1991).

What is the most effective way to assure a wary public of the safety of spray residues in fruits and vegetables? The beliefs and perceptions of a poorly informed public are so strongly influenced by simplistic media reporting of health concerns related to pesticide use and residues. Rachel Carson made pesticides a public issue and sensitive analytical chemistry regularly confirms the reality of trace levels of exposure. There is inordinate concern for the hazardousness of invisible amounts of chemicals that are economically classed as pesticides so long as they can be detected in our environment until they are finally mineralized.

1. At the cash register in the market there is a difference. Pesticide free produce is more expensive than other fruits and vegetables. If pricing and signage are removed, produce stands as it is—judged good if it tastes good! In the first analysis our apples are apples; and they are good, if they taste good! Flavor trumps price and appearance.

2. Can the apples be distinguished by their basic chemical composition? What do the Nutrition Facts reveal of the proximate analysis of two apples? Using the same type of label that appears on most of our foods, we can learn that the apples are mostly water and supply mostly complex carbohydrates and some vitamin C of the things we know we need.

3. More detailed specific information about the chemicals and nutritional values of the produce is also readily available. We might be able to show more of one or the other of vitamins or minerals, but since we are not operating at a level where produce of any kind limits our survival, those differences are tiny and of not of nutritional consequence. Nutrition data are available http://nutritiondata.self.com/help/about for many of the foods we regularly consume.

4. Denial claims are common in the marketplace and may influence the choicing of some consumers—no cholesterol, no fat, no sodium, for example. In the end appearance and flavor seem to be time-tested attributes that are sought and bought and eaten. These attributes are well known to plant breeders, but at this time are not chemically defined by plant breeders or consumers.[2]

5. Only when chemicals in sprayed produce are measured in parts per million or parts per billion, in amounts that have been scientifically demonstrated to have no biological effects, do we finally have a means to chemically distinguish the sprayed and the unsprayed apples. And even that takes some pretty amazing arithmetic! Have a look at these examples:

a. What is the significance of consumption of an average 175 g apple containing a 5 ppm pesticide residue with an LD50 of 3100-3600 mg/kg and a NOAEL of 10 mg/kg?
b. The dose would be 175 g x 5 ppm (ug/g) = 875 ug or the dosage (175 g x 5 ug/g)/ 70kg = 12.5 ug/kg or 0.0125 mg/kg so we can compare it to test results.
c. The rat oral LD50 is 3100-3600 mg/kg so it is definitely not the fabled poisoned apple! And a No Observed Adverse Effect Level (NOAEL) of 10 mg/kg from a 2 year feeding study in rats based upon decreased weight gain and cellular changes in the liver and thyroid gland is a very conservative reference point since no single dose effects were observed. Clearly there is a large Margin-of-Safety (or Margin-of-Exposure since our reference point is the NOAEL).
Margin-of-Exposure = NOAEL/actual dosage = 10 mg/kg/0.0125 mg/kg = 800

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[2] Even vitamin C could limit extreme hypothetical exposures before the NOAEL of 800 apples is consumed. Each 125 g serving of apple contains about 5.7 mg vitamin C or 10% of our Daily Value according to the USDA. But the Tolerable Upper Limit for vitamin C is 2000 mg, a dose sufficient to cause stomach pain, discomfort and diarrhea.
175/125 x 5.7 = 8 mg vitamin C in our apples, so only 2000/8 = 250 apples represents vitamin C overdose

d. How many 175 g apples would have to be eaten to get to the NOAEL?
   (NOAEL x body weight x 1000)/(ppm x serving size) = 800 apples
e. How many pounds of apples is that?
   Servings x serving size x 0.002205 lbs/g = 309 pounds (6-7 bushels)
f. Relationship of the amount of consumption to the weight of the consumer?
   Body weight/(2.2 lbs/kg)]/70 kg = (309 lbs)/(2.2 lbs/kg)]/70 kg = 2 times body weight

In conclusion, hypothetical estimates can be made to represent differences between sprayed and unsprayed produce—the arithmetic would look be similar, but in every case differences between the sprayed and unsprayed produce would only exist at the lowest level at which chemical measurements were made. The appearance, flavor, and other attributes of the produce are destroyed during the process of chemical analysis. And only at the lowest levels of analysis where pesticide residues distinguish sprayed and unsprayed produce. The amounts represent exposures where there is "reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information." By any measure that could be used to demonstrate risk, sprayed and unsprayed produce represent safe food so far as pesticide residues are concerned.

Agricultural Dust Contributions to Air Quality Issues

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The San Joaquin Valley Air Pollution Control District (District) has the regulatory responsibility for identifying the changes that need to be made to continue improving our air quality and to establish regulations, guidance documents, and incentive programs to guide progress. However, the support and cooperation of the Valley's agricultural community, the public's involvement, and the investments of Valley businesses are essential for these programs to be effective. The agricultural community, including growers, processors and supporting services such as pest management, have provided a valuable contribution to the San Joaquin Valley's air quality improvements in recent years. Through the District's Conservation Management Practices and Confined Animal Facilities rules, over 6,000 farms and agricultural operations have contributed to significant reductions in both particulate matter 10 microns or less in diameter (PM10) and volatile organic compounds (VOCs). Open burning of agricultural materials has been gradually phased out since 2004 through the District's open burning rule. District incentive programs have assisted the agricultural community to accelerate replacement of irrigation engines and tractors with cleaner and more efficient models. The purchases made through incentive programs do require an investment by the purchaser. Agribusiness has contributed its share of effort during a difficult economic period both in complying with requirements and participation in voluntary incentive programs that involve additional expense on their part.

During the last few years, the federal government has reviewed and tightened national ambient air quality standards based on new health assessments of the impact of air pollution. As federal health-based air quality standards become increasingly stringent, the Valley continues to face some of the nation's most difficult air quality challenges for reducing ozone and particulate matter 2.5 microns or less in diameter (PM2.5). The impact on agribusiness cannot be determined until we identify appropriate and sufficient actions to meet the new standards. To make this assessment, we must have a clear understanding of the contributing sources and their emissions and what actions remain that could further reduce these emissions.

In response to the impending tighter standards, the District has been evaluating air pollutant emissions from sources in all sectors of activity to identify opportunities for cost-effective regulations, incentive-based measures, and other innovative strategies and programs. The District conducts detailed analyses and research projects to better understand the Valley's emissions sources and potential emissions control technologies and practices. The District's *2008 PM2.5 Plan* included feasibility study commitments to evaluate sources for which PM10 emissions and controls are well established, but for which there was insufficient data at the time of the plan to establish PM2.5 emissions and control opportunities. Current evaluations pending or in progress include particulate emissions from cotton gins, evaluation of the District Conservation Management Practices program for PM10 to determine effectiveness for PM2.5, and evaluation of Regulation VIII (Fugitive PM10 Prohibitions) to determine the contribution of these sources to direct PM2.5 emissions. Each review is intended to evaluate the potential of control technologies and practices to reduce PM2.5 emissions. Some of this analysis is being conducted under the California Regional Particulate Air Quality Study (CRPAQS) and Central California Ozone Study (CCOS) programs. Project measurements are conducted by independent scientific investigators, who are generally selected through a request for proposal (RFP) process based upon their qualifications to conduct the required research. The results of these studies are reviewed by groups that include technical experts, regulators, and representatives of the affected stakeholder community. Many of these projects result in professional journal articles or other publications that are submitted to additional peer review for the soundness of the methods and conclusions.

The District presentation at this meeting will provide an overview of District and other related recent efforts to better understand the role of agricultural emissions in the Valley's ozone and PM2.5 air quality as well as the additional analytical work that is planned for the near future through the CCOS and CRPAQS programs.

Groundwater Nitrate in the Tulare Lake Basin and Salinas Valley

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Introduction

Nitrate is the most frequently detected groundwater contaminant in California's groundwater. Fertilizer use, manure leaching from storage lagoons, manure applications to forage crops, septic tank leaching, and intentional recharge of municipal and industrial effluent contribute to groundwater nitrate contamination. Nitrate concentration exceeding the maximum contaminant level (MCL) for drinking water (45 mg/L as nitrate of 10 mg/L as nitrate-nitrogen) affects approximately 10% of California's public drinking water supply. In rural areas, many residents rely on domestic wells. Few data are available, but recent surveys have shown that typically 2 to 10% of domestic wells exceed nitrate standards. In intensively cultivated agricultural regions, a significantly higher number of domestic wells may be affected. In a recent survey of domestic wells in Tulare County, the State Water Resources Control Board (SWRCB), through its Groundwater Ambient Monitoring Program (GAMA), found over 40% of domestic wells to exceed the drinking water standard.

Already in the 1970s, high nitrate values were reported, e.g., in eastern Fresno County (Schmidt, 1971). More than a decade later, the state legislature ordered a report on the state of nitrate in groundwater and possible solutions (Anton et al., 1988). In the mid-1980s, 60% of domestic wells surveyed in a research study near Hilmar, Merced County, exceeded the nitrate MCL. In the Tulare Lake Basin area, high nitrates have been noted since the 1970s in a discontinuous belt along the eastside of the Valley from Fresno County to Kern County and including communities from Dinuba, Woodlake, Lindsay, Strathmore, Porterville, Exeter, down south to McFarland, Wasco, Bakersfield, Arvin, Edison, and Lamont. In the Salinas Valley, as much as 50% of monitored wells in the 1980s exceeded the nitrate drinking water standard. Providing a statewide, thorough summary of the extend of nitrate contamination, the 1989 Nitrate Working Group (Stephany et al., 1989) recommended that the California Department of Food and Agriculture (CDFA) implement the following actions:

- identify nitrate sensitive areas in California
- establish priority areas to implement nitrate control programs
- establish nitrate management progams in sensitive areas
- develop best management practices
- establish research and demonstration projects on nitrate control through irrigation, fertilizer, and manure management

The CDFA created the Fertilizer Research and Education Program (FREP) funded through a fertilizer tax. The program has focused primarily on the development of best management practices, but has failed at establishing clear linkages between nutrient management practices and groundwater quality. It is has also been questioned, whether the program has significantly affected fertilizer management practices (Franco, 1994). Over the past 25 years, perhaps the most significant change in agricultural practices, at least in some regions (Salinas Valley, Westside of the San Joaquin Valley/Tulare Lake Basin) has been a significant increase in irrigation efficiency and uniformity, which has led to significant reduction in water leaching to groundwater, and possibly to lower nitrogen loading rates. The latter effect is hypothesized and little research is available to date to test this hypothesis specifically for the Central Valley or Salinas Valley.

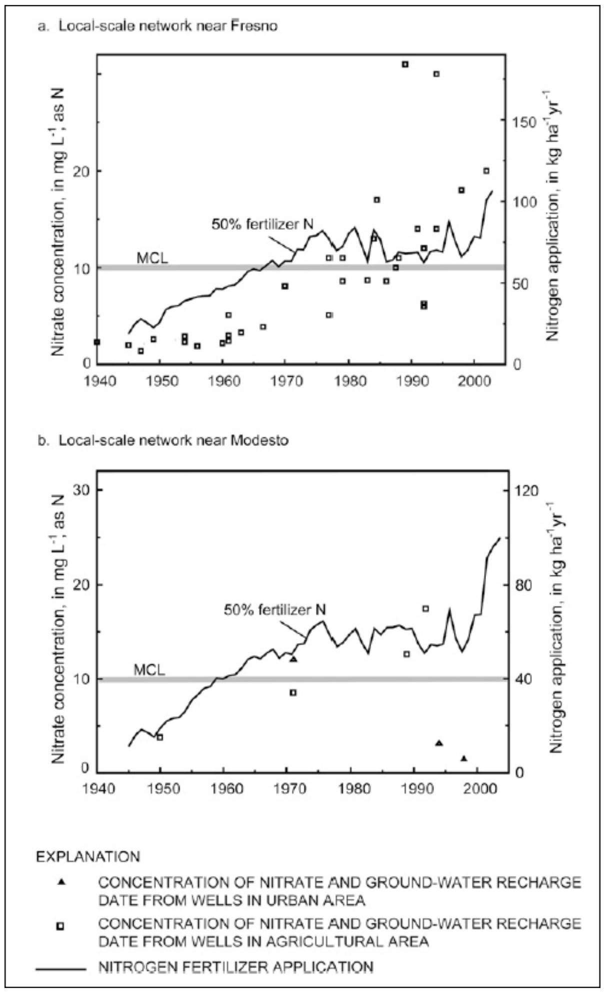

Figure 1: Estimated concentrations of nitrate in recharge and observed concentrations of nitrate in monitoring wells in (1) Fresno, California and (b) Modesto, California (*from*: Burow et al., J. of Environ. Qual., 2008).

Since the 1988 Report to the Legislature, nitrate contamination in many communities has worsened, more wells have been affected by MCL exceedances, and the depth of nitrate contamination in the upper aquifer of the Central Valley aquifer system has deepened (Burow et al., 1998, 2008). Research shows that today's groundwater nitrate contamination is the result of five decades of nitrate pollution and what is extracted for drinking water today may have been recharged thirty, forty, or fifty years ago (Tesoriero et al., 2007; Burow et al., 2008; VanderSchans et al., 2009).

Many of the communities affected by drinking water standards are in California's agricultural regions, which are economically disadvantaged ("disadvantaged communities" or DACs, defined as communities with a median household income less than 80% of the state's median income) or severely disadvantaged communities (defined as communities with a median household income less than 60% of the state's median household income). The communities struggle to finance, plan, and maintain public water supply systems that can provide clean drinking water. The problem of domestic well water pollution remains an altogether unaddressed drinking water problem.

The federal Clean Water Act has been largely ineffective at protecting the drinking water resources of these communities and rural households as it applies only to (navigable) surface waters, while over 90% of the drinking water supply in the Central Valley and Salinas Valley is from groundwater. In California, the 1968 Porter-Cologne Act goes above and beyond the provisions of the federal Clean Water Act in that it explicitly requires the protection of both surface water AND groundwater resources for beneficial uses. Until 2002, all major anthropogenic sources of groundwater nitrate were held to voluntary standards of groundwater protection. Since then, the State Water Resources Control Board (SWRCB) and its Regional Water Quality Control Boards (RBs) have embarked on regulating an increasing number of industries that potentially pollute groundwater through diffuse nonpoint source discharge. Among agricultural producers, Central Valley's dairy industry was the first to be regulated under new waste discharge waivers for groundwater protection; in 2011, all of irrigated agriculture will follow suit under a new Irrigated Lands Regulatory Program in the Central Valley and under the Agricultural Regulatory Program in the Salinas Valley/ Central Coast region. In addition, food processors, municipal wastewater treatment plants discharging to groundwater, and other groundwater dischargers of salts and nutrients will be regulated in the near future under the development of so-called salt and nutrient basin plan amendments in all nine regions of the SWRCB (see, for example, the Central Valley efforts at http://cv-salinity.org).

Not withstanding these efforts, the California Legislature, in 2008, requested the California Department of Public Health to authorize a comprehensive pilot study on groundwater nitrate, to be implemented by the SWRCB, which will issue a Report to the Legislature in May of 2012. In May of 2010, SWRCB contracted with the University of California to implement this pilot study, which will provide significant scientific, technical, and policy guidance to the various stakeholders involved in the ongoing regulatory programs on the nitrate source side (dairy regulatory program, irrigated lands regulatory program, salt and nutrient basin plan amendments) and also to the Department of Public Health and others involved in the protection of drinking water consumers, community development, and landuse planning. Beyond these programs, the pilot study will provide a significant baseline data compendium for the management of water resources at the regional level under the Integrated Regional Water Management Plans (IRWMPs) in the pilot basins and elsewhere.

Approach

Senate Bill 2X1 (SB 2X1), section 83002.5, requires the State Water Board, in consultation with other agencies, to develop pilot projects in the Tulare Lake Basin and the Salinas Valley that focus on nitrate contamination. The objectives of the work to be conducted within the pilot project basins by UCD are (http://www.waterboards.ca.gov/water_issues/programs/nitrate_project/index.shtml):

- Identify sources, contributions, and reduction/prevention options for nitrate in groundwater
    - Identify sources, by category of discharger, of groundwater contamination due to nitrate in the Tulare Lake Basin and the Salinas Valley (pilot project basins).
    - Estimate proportionate contributions to groundwater contamination by source and category of discharger.
    - Identify and analyze options to reduce current nitrate levels and prevent continuing nitrate contamination of the pilot project basins and estimate the costs.
- Identify methods and costs associated with treatment or alternative water supply for nitrate contaminated groundwater
    - Identify methods and costs associated with the treatment of nitrate contaminated groundwater for use as drinking water.
    - Identify methods and costs to provide an alternative water supply to groundwater reliant communities in each pilot project basin.
- Identify all potential funding sources including, but not limited to, state bond funding, federal funds, water rates, and fees or fines on polluters
    - Identify funding sources to provide resources for the cleanup of nitrate in groundwater.
    - Identify funding sources to provide resources for the treatment of nitrate in groundwater.
    - Identify funding sources to provide resources for the provision of alternative drinking water supply of nitrate in groundwater.
- Develop recommendations for groundwater cleanup programs
    - Identify recommendations for developing a groundwater cleanup program for the Central Valley Water Quality Control Region based upon pilot project results.
    - Identify recommendations for developing a groundwater cleanup program for the Central Coast Water Quality Control Region based upon pilot project results.
- Participate in an interagency task force
    - The University of California Davis will participate in the Interagency task force that includes the; State Water Board, California Department of Public Health, Department of Toxic Substances Control, California Environmental Protection Agency, Department of Water Resources, Department of Food and Agriculture, Department of Pesticide Regulation, and local public health officials.

The project is implemented by an interdisciplinary team of researchers at the University of California Davis in collaboration with researchers from other universities and agencies, in collaboration with local and state agencies, and stakeholders. The principal components of the analysis are briefly outlined here.

The nitrogen loading assessment will be primarily conducted through a mass balance analysis at the landuse parcel level. Land parcels are assigned current (and historic) landuse categories (natural, urban, and agricultural, where each of these categories are further subdivided). Nitrogen inputs (fertilizer, manure, atmospheric deposition) and nitrogen removal (harvest, atmospheric losses) are considered to estimate groundwater losses of nitrogen by closure to a simple mass balance. For each category current nitrogen budgets are developed based on available data, recommended and/or documented practices associated with individual landuses, literature or agency reports of nitrogen applications, nitrogen discharges, (in the case of agricultural commodities:) harvest amounts (crop removal). Results are checked against field data of groundwater nitrogen losses, where available. The assessment will be done for the present time, but also for historic and future landuse conditions to better understand the effect of historic landuse on current and future groundwater nitrate levels.

Nitrogen loading reductions will be assessed by compiling and reviewing literature on agronomic, irrigation, and fertilization practices, through interviews of extension agents and agricultural consultants, and through implementation of expert panels. Economic costs of nitrogen source reduction measures are assessed through economic analyses of key alternatives to N loading reduction.

A thorough assessment of past, current, and future groundwater nitrate distribution is key to first, understand the contributions of historic landuses to current and future groundwater quality and second, to identify the affected population (current and future) that may need to treat drinking water or obtain alternative water resources (susceptible population) due to past and current groundwater pollution with nitrate. The groundwater assessment will be performed in two tracks: First, a comprehensive assessment of past and current groundwater nitrate data will be performed to establish a geographic information system (GIS) database that identifies not only nitrate levels, but also attempts to identify the depth from which groundwater is obtained. Private and public, local, regional, state, and federal resources and databases will be combined into a single comprehensive database, while protecting existing confidentiality and homeland security agreements. The database will be used to provide a comprehensive assessment of historic and current groundwater nitrate and trends in the pilot project areas. A second track will be to establish an explicit linkage between nitrogen loading and historic and current groundwater nitrate by implementing a groundwater modeling study that tracks nitrate loading from the source to the well and computes not only the travel path but also the travel time, potential nitrogen reaction, and nitrate dispersion/dilution in the aquifer and in the well intake screen. The groundwater nitrate model provides a tool to assess future groundwater nitrate conditions (time horizon: 1950-2050) under current and alternative landuse management scenarios.

Treatment options are compiled and treatment cost estimates developed through an extensive review of literature and industry sources, and through a survey of public water suppliers in the pilot basins. Treatment costs will take into account the effects of potential co-contaminants found in the study area.

The assessment of treatment and alternative water supply options relies on a better understanding of the current service areas of public water supply systems, particularly of the smaller and very small public water supply systems, and on a delineation of areas depending entirely on domestic wells for their drinking water supply. An economic assessment of water supply alternatives will be implemented.

Rapid project progress depends heavily on already existing expertise within and outside the principal investigating team at UC Davis; and on a number of already ongoing studies that have direct links to this project including the California Nitrogen Assessment implemented by the Agricultural Sustainability Institute at UC Davis, collaborative work on water treatment between UC Davis and the California Department of Public Health, agricultural economic studies of nonpoint source pollution in the Central Valley for the Central Valley salinity program (http://cv-salinity.org), ongoing groundwater modeling studies in the Central Valley and Salinas Valley by various research groups and agencies, extensive groundwater quality assessment under the SWRCB GAMA program, and the USGS National Water Quality Assessment Program, and other ongoing work. A draft and final report will be submitted by the University of California team in September and December of this year, respectively.

Literature Cited

Anton, E.C., J.L. Barnickol, and D.R. Schnaible, 1988, Nitrate in Drinking Water – A Report to the Legislature, Report No. 88-11WQ, October 1988, Division of Water Quality, State Water Resources Control Board, State of California, Sacramento, California.

Burow, K.R., S.V. Stork, and N. Dubrovsky, 1998. Nitrate and pesticides in groundwater in the Eastern San Joaquin Valley: Occurrence and trends. U.S. Geological Survey Water Resources Investigations Report 4040a, 33p.

Burow, K.R., J.L. Shelton, and N.M. Dubrovsky, 2008. Regional nitrate and pesticide trends in groundwater in the Eastern San Joaquin Valley, California, J. Environ. Qual. 37:S-249-S-263.

Franco, J., S. Schad, and C.W. Cady, 1994. California's experience with a voluntary approach to reducing nitrate contamination of groundwater: The Fertilizer Research and Education Program (FREP). J. Soil Water Conser. 49:76-81.

Schmidt, Kenneth D., 1971. The Distribution of Nitrate in Groundwater in the Fresno-Clovis Metropolitan Area, San Joaquin Valley, California, May 1971, Ph.D. thesis, Hydrology; Advisor: J.W. Harshbarger, Department of Hydrology and Water Resources, University of Arizona, Tucson, Arizona.

Stephany, P.W., L.J. Butler, P. Lowry, J. Letey, R. Millaway, J. Miller, S. Pettygrove, D. Ririe, D. Rush, D. Schnaible, S. Shaffer, and P. Stoddard, 1989. Nitrate and California Agriculture, Nitrate Working Group, California Department of Food and Agriculture, February 1989, 66 pages.

Tesoriero, A.J., D.A. Saad, K.R. Burow, E.A. Frick, L.J. Puckett, J.E. Barbash, 2007. Linking groundwater age and chemistry data along flowpaths: Implications for trends and transformations of nitrate and pesticides. J. Contam. Hydrol 94:139-155.

VanderSchans, M.L., T. Harter, A. Leijnse, M.C. Mathews, R.D. Meyer, 2009. Characterizing sources of nitrate leaching from an irrigated dairy farm in Merced County, California. J. Contam. Hydrol. 110:9-21.

Reducing Volatile Organic Compound Emissions from Pesticides through Reformulation

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Volatile organic compounds (VOCs) and nitrogen oxides react with sunlight to form ozone, a major air pollutant. In California, there are several regions which do not meet either federal or state ambient air quality standards for ozone. To help attain the ozone air quality standard, California's state implementation plan for the federal Clean Air Act requires the Department of Pesticide Regulation (DPR) to reduce VOC emissions from pesticides by specified amounts in certain ozone nonattainment areas. DPR is required to maintain an emission inventory to track VOC emissions and reduce pesticide emissions by specified amounts during the May through October peak ozone season. Fumigants and inert ingredients in products formulated as emulsifiable concentrates are the major pesticide VOC contributors.

Regulations to reduce VOC emissions from fumigants went into effect in 2008. The regulations require the use of low-emitting fumigant application methods in nonattainment areas during the highest ozone period of May to October. In one nonattainment area, Ventura County, a system of allocating VOC emission allowances to growers has been necessary to reduce the VOC emissions to the required levels. So far, emission allowances have not been required in the other nonattainment areas.

In areas were fumigant use is low in relation to nonfumigant use, emission reductions may need to come from other pesticide use rather than fumigants. DPR is currently evaluating the feasibility of reducing VOC emissions from emulisfiable concentrate products containing seven active ingredients with the greatest VOC contribution in the San Joaquin Valley: abamectin, chlorpyrifos, dimethoate, gibberellins, oxyfluorfen, permethrin, and trifluralin.

American Society of Agronomy
California Chapter

2011 Poster Abstracts

Poster Chair:

Rodrigo Krugner

POSTER SUBMISSION: STUDENT

Title of Paper: **Screening for Phytophthora capsici Disease Resistance and a Resistance QTL in Various Lines of Pepper**

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ABSTRACT:

Phytophthora capsici (the pepper blight pathogen) causes some of the most severe disease in pepper, worldwide, by attacking roots, leaves, stems, and fruits. This project involves determining the disease resistance to several different races of *P. capsici* of 45 accessions of *Capsicum* (representing 5 different species) from the USDA *Capsicum* Core Collection, and testing those same accessions for the presence of the *Phyto 5.2* quantitative trait locus, which is one of the major loci conferring resistance to this pathogen. Three different inoculation procedures were used, one for examining root rot resistance, and two for examining foliar blight resistance. The first assay used 10,000 zoospores inoculated into the soil around a seedling as a means of infection. The second assay is a detached leaf assay, which involves using a suspension of macerated mycelia in sterile, deionized water. Droplets of the suspension are placed on leaves. The third assay is another detached leaf assay, where plugs of mycelium are placed directly on the leaves, pathogen side down. Differential responses were seen on different accessions using all three techniques, and different isolates of the pathogen elicited different patterns of response. Genomic DNA isolations are being performed right now and preliminary PCR for the identification of *Phyto 5.2* are being run. Amplification of the diagnostic band has been seen in several accessions. When PCR results are completed and replicated, correlation analysis between resistance to different isolates and the presence of the QTL will be done. This work is being supported by a Crop Germplasm Committee Grant from the USDA.

POSTER SUBMISSION: STUDENT

Title of Paper: **Selenium Incorporation and Partitioning in 'Jose' Tall Wheatgrass (Thinopyrum ponticum cv. Jose) Irrigated with Saline Drainage Water**
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ABSTRACT:

In the western San Joaquin Valley (SJV) of California, re-use of saline drainage water (DW) for irrigation has been conducted primarily to dispose of selenium (Se)-enriched DW with minimal impact to the environment. Due to extreme water shortages in recent years, this DW is now viewed as a valuable alternative water source, particularly for forage production. 'Jose' tall wheatgrass (TWG) is a highly salt tolerant forage that has performed well, having adequate dry matter production and quality even when grown in soils of 20 dS/m ECe. In soils where Se is very high, this forage has accumulated up to 10 mg Se/kg DM when abundantly irrigated with saline DW. Conversely, in the eastern SJV, soils are low in Se and dairy cattle producers often supplement their animals with inorganic sodium selenate. In fact, lactating cows are responsible for an approximate annual input of 3405 kg of Se into the San Joaquin and Sacramento Valleys, primarily as feed additives. The overall goal of the research is to evaluate the potential of utilizing TWG as a substitute for Na selenate in cattle diets. Specifically, our objective is to identify management practices resulting in higher Se incorporation in TWG and to determine its bioavailability for cattle. A greenhouse study was initiated with irrigation waters of two salinities (EC 3 and 12 dSm^{-1}) and two selenium concentrations (350 and 1000 ppb), along with three cutting heights (20, 40, 60 cm) arranged in a split plot design with the forage grown in pots containing a 60:40 mix of field soil and sand. Data on Se accumulation and soil and irrigation water characteristics will be presented.

POSTER SUBMISSION: STUDENT

Title of Paper: **Nitrous Oxide and Carbon Dioxide Emissions from Tomatoes Subjected to Open Field CO2 Canopy Enhancement**

Authors: Natalio Mendez, Dave Goorahoo, Florence Cassel S., & Gerardo Orozco
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ABSTRACT:

Increase in atmospheric greenhouse gas (GHG) concentrations, including those stemming from nitrous oxide (N2O) and carbon dioxide (CO2), has been partly attributed to agricultural and industrial activities. N2O is emitted from soil during addition of fertilizers and CO2 can be released from sequestered carbon during agricultural practices. Thus, sustainable agricultural practices are necessary to minimize GHG emissions while maintaining optimal crop production. Particularly, it is important to quantify N2O emissions in fields fertilized with N sources and subjected to elevated atmospheric CO2 levels. The objective of this study was to quantify N2O and CO2 concentrations from soils with tomatoes grown under both ambient and elevated CO2 levels. The tomatoes were irrigated with a sub-surface drip and fertilized with Urea Ammonium Nitrate and Calcium Ammonium Nitrate. In elevated CO2 plots, CO2 was applied through surface drip lines. N2O and CO2 concentrations were determined with a Photoacoustic Field Gas-Monitor- INNOVA® 1412- and an EPA approved flux chamber assembly. Measurements were conducted at 84, 106 and 114 days after transplant (DAT). For the CO2 enriched plots, mean daily CO2 levels within the crop canopy ranged from 580ppm to 400 ppm during the 7 hours of application. Ambient CO2 concentration was 358 ppm. For the CO2 enriched plots, mean N2O concentration decreased from 0.22 (±0.02) ppm on 84 DAT to 0.14 (±0.02) ppm on 114 DAT. In contrast, there was an increase in the N2O levels from 0.04 (±0.01) to 0.17 (±0.03) ppm from the plots where tomatoes were exposed to ambient conditions. Generally, there was a moderate ($r = 0.64$) negative correlation between the N2O levels measured in the CO2 enriched plot versus those measured in the ambient plots.

POSTER SUBMISSION: STUDENT

Title of Paper: **Evaluation of Germination Tests for Screening of Salinity Tolerance in Turfgrasses.**

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ABSTRACT:

Turfgrasses cover approximately 1.9% of the total land surface of the United States, making it the single largest irrigated crop in the nation. The most recent drought and resulting water restrictions have reduced the availability of irrigation water for use in these turfgrass systems. To address this, many turf managers are considering, or have adopted, use of reclaimed water for irrigation. This is not without problems, primarily due to the often higher salinity of such water. Many turf managers are seeking cultivars tolerant of saline conditions. Unfortunately, little data exists on effective methods for screening turfgrass germplasm for salinity tolerance. In addition, there is little agreement among turf breeders, university and industry researchers as to which screening methods are most effective. The objective of this study was to directly address this concern. Three most commonly used methods: 1) *in vitro*, 2) hydroponic, and 3) sand-based methods were evaluated. Six cultivars of turf-type Tall Fescue (*Festuca arundinacea* Schreb.) were selected based on a range of salinity tolerance data: Grande II, Watch Dog, Tulsa II, Grande, Tulsa Time and Speedway. This study involved the application of a selection pressure (NaCl) at increasing concentrations (0, 10, 20 and 30 dS/m) using each of the above methods. Seed germination rates and approximate salt concentration leading to a 25% or 50% reduction in germination were used as selection criteria. The use of controlled environment experiments eliminated field-derived variability and allowed for large quantities of germplasm to be assayed in the most cost-effective and timely manner. Results will be presented from this study, and will be essential for efforts to establish a uniform methodology for use in turfgrass salinity tolerance selection

POSTER SUBMISSION: STUDENT

Title of Paper: **Paraquat mechanism of resistance influenced by light intensity in hairy fleabane paraquat-glyphosate resistant biotype from California**

Authors: Marcelo L. Moretti, Bradley Hanson, Nathalia N. Mourad, John Bushoven, and Anil Shrestha
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ABSTRACT:

Paraquat resistance has been reported worldwide in 25 species since the 1960's when it was first introduced. In the USA, only five species are known to have evolved such resistance. The most recent case of paraquat-resistance was documented in a hairy fleabane population in Fresno County, California. Further, this population was multiple-resistant to paraquat and glyphosate, which is the first case in the world. As such, there is no specific information on mechanism of resistance. However, previous studies of paraquat resistance in a closely related weed species, horseweed (<C. canadensis>), utilizing chloroplast fluorescence measurements indicated that resistance is due to sequestration of the herbicide into cell vacuoles and this process was light dependent. Therefore, the objective of this study was to evaluate the effect of paraquat treatments under different light intensity on rate of photosynthesis correlating with chloroplast fluorescence measurements in known paraquat-glyphosate susceptible (S) and resistant (R) biotypes of hairy fleabane. Results indicated that presence of light promoted a rapid injury in both R and S plants but that, in the absence of light, the phenomenon was less pronounced. This study showed that the R plants survived applications of paraquat regardless of presence or absence of light; however, light did affect the rate of recovery. This may indicate that light intensity is correlated to the magnitude of resistance what would be in agreement with findings reported in the literature with paraquat resistant horseweed.

POSTER SUBMISSION: STUDENT

Title of Paper: **Sweet corn yield as affected by three plant density and three nitrogen levels**
Authors: Nathalia Mourad, Ganesan Srinivasan, Anil Shrestha, John Bushoven
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ABSTRACT:

California is the second largest state in sweet corn fresh market production, with 16% of the country's total production. Fresno County is the leader in production with 29.9% of the state's total value of fresh market sweet corn Nitrogen (N) is an essential element for plants and it can contribute to yield increase, however, there are environmental issues regarding high doses of this fertilizer. On the other hand, plant density affects the competition between plants in the field and consequently final yield. Sweet corn hybrids perform different under a particular environment and management. Therefore, the objective of this study was to look for the best combination of N level and plant density for Mirai 148Y hybrid in Fresno County. Three N levels (165, 225 and 280kg/ha) and three plant densities (60k, 75k and 90k seeds/ha) were tested. The highest yield was achieved by the lowest population and 225kg N/ha.

POSTER SUBMISSION: STUDENT

Title of Paper: **Soil Respiration and Yields for Tomatoes Grown with Elevated Carbon Dioxide Levels**

Authors: Gerardo Orozco, Florence Cassel S., Dave Goorahoo, Shawn Ashkan & Natalio Mendez
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ABSTRACT:

Anthropogenic inputs of carbon dioxide (CO_2) have increased overall CO_2 concentrations in the atmosphere leading to global climate change. The three controlling factors over soil respiration have been identified as soil temperature, soil moisture, and carbon (C) substrate. Thus elevated CO_2 concentrations may influence soil respiration indirectly by regulating plant growth, soil water and ground C assimilation. Our overall goal is to evaluate efforts aimed at identifying and achieving optimum crop productivity and water use efficiency in vegetable cropping systems. In this phase, the aim was to assess the effects of varying CO_2 levels applied to tomatoes on yield and soil respiration rates. During the summer of 2010, tomatoes were planted on a sandy loam soil at the University farm in Fresno, CA. There were 20 rows of non-CO_2 treated, a buffer of 7 rows and 20 rows that were enriched with CO_2 which was applied through surface drip lines. Daily levels of atmospheric CO_2 within the plant canopy were monitored using CO_2 Analyzers. A CIRAS-2 portable photosynthesis system with an attached CO_2 flux chamber was used to measure the soil respiration rates. For the CO_2 enriched plots, mean daily CO_2 levels within the crop canopy ranged from 580ppm to 400 ppm during the 7 hours of application. Mean ambient CO_2 concentration was 358 ppm. There was no significant difference ($\alpha \geq 0.05$) in both the soil respiration rates and tomato yields between CO_2 enriched and non-enriched plots. Generally, soil respiration rates decreased during the course of the study. Future work will focus on the collection of additional parameters (e.g. soil moisture and SOM) for input into models for characterizing C dynamics within vegetable cropping systems.

POSTER SUBMISSION: STUDENT

Title of Paper: **Yield and Blossom End Rot in Tomatoes Fertigated with Calcium Thiosulfate**

Authors: Prasad Yadavali, Florence Cassel S., Dave Goorahoo and Sharon Benes
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ABSTRACT:

Many growers in the San Joaquin Valley of California are transitioning to higher value crops and more efficient irrigation systems to maximize production yields. For example, growers who faced low returns from cotton under flood irrigation practices are now growing vegetable crops, such as tomatoes, using drip irrigation system. However, such transition poses some new challenges, particularly in heavy clay soils affected by saline-sodic conditions. Such problems include the sensitivity of vegetable crops to salinity and their susceptibility to diseases and calcium (Ca) deficiency. Therefore, the challenge is to increase soil Ca availability to plants and reduce soil pH in the root zone in order to ensure maximum crop yield and quality. The objective of our study was to evaluate the effect of Ca-Thiosulfate fertigation on yield and blossom-end rot (BER) of processing tomatoes grown in salt-affected soils. In a Randomized Complete Block Design (RCBD), with four replicates, Ca-Thiosulfate was compared with three other treatments comprising of Ammonium Nitrate, Calcium Ammonium Nitrate and Urea Sulfuric Acid (US-15). The experiment was conducted in Kettleman City, CA on a Lethent silty clay with a salinity range of 2-8 dS/m within the 0-1 ft depth. In 2009, tomatoes fertigated with Ca-Thiosulfate had the highest significant yield (66.2 Tons/acre; $p<0.002$). However, no significant difference among treatments was found in 2010 with the average yield being 37.49 ± 10.39 Tons/acre. There was a significant difference in the number of blossom-end rots in both years with the highest numbers obtained for the US-15 treated tomatoes and lowest with Ca-Thiosulfate treatment. Also, there was no significant difference in tomato Brix level in both years.

POSTER SUBMISSION: STUDENT

Title of Paper: **Yield of a Fresh Market Tomato Cultivar Subjected to Regulated Deficit Irrigation**
Authors: David Scheidt, Dave Goorahoo, Florence Cassel S., Anil Shrestha and Prasad Yadavali
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ABSTRACT:

Tomato cultivar (cv) PS 2942 is a determinate cultivar with an extensive crop canopy and extra large fruit size. Cv PS 2942 has shown promising yields in commercial production. However, there is a need to determine the optimum water use efficiency for PS 2942. The purpose of the current study was to evaluate the impact of three irrigation regimes of regulated deficit irrigation (RDI) on the yield of PS 2942. A Randomized Complete Block Design (RCBD) experiment with four treatments and five replications was conducted on sandy-loam soil at the Center for Irrigation Technology in Fresno, CA. Plants in Treatment 1 were irrigated at 100% ET from plant establishment until harvest. In Treatment 2 the crop was irrigated at 75% ET from plant establishment until first fruit set (Stage 1). In Treatment 3 the crop was irrigated using 75% ET from first fruit set until harvest (Stage 2). In Treatment 4, the crop was irrigated at 87.5% ET from plant establishment until harvest. Tomatoes were transplanted on July 7th, 2010 and harvested on November 16th, 2010. The crop was irrigated with subsurface drip irrigation and routinely fertilized using CAN-17 and UAN-32. There was no significant difference in yields among the three RDI treatments. The average yield of marketable green fruit harvested from 10 plants was 24.12 (±6.76) kg. The average yield of marketable red fruit was 4.40 (±1.74) kg. The average yield of marketable breakers was 4.10 (±1.14) kg. These findings from the first year of the study indicate that similar yields can be achieved using the three RDI treatments, and that timing of the water stress during the growing cycle had no significant effect on yield. The experiment will be repeated in 2011.

POSTER SUBMISSION: STUDENT

Title of Paper: **Use of Selenium-enriched Mustard and Soy Seed Meals as Potential Bioherbicides and Green Fertilizer in Organic Spinach and Broccoli Production.**

Authors: Annabel Rodriguez Gary Banuelos, Sajeemas Pasakdee, and Anil Shrestha
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ABSTRACT:

New plant-based products can be produced from seed harvested from Brassica species used for phytomanaging selenium (Se) in the west side of central California. Se-enriched seed meals produced from white mustard (*Sinapis alba*) plants and plants were tested as potential bioherbicides and green fertilizers in spinach (*Spinacea oleracea*) and broccoli (*Brassica oleracea)* production under organic field conditions for one growing season. Treatments consisted of adding either mustard meal (containing 2.2 mg Se/kg dry mass) or control-soybean meal (containing <0.1 mg Se/kg dry mass) (*Glycine max* L. Merr.) to the soil at rates equivalent to 0.5 and 2 t/acre, respectively, 2 ½ weeks before planting. During the growing season we observed that mustard meal treatments (especially high) lowered the emergence of resident winter annual weeds more than soy meal treatments. High rates of mustard meal reduced hand weeding time and weed biomass by almost 50% compared to all treatments. Fresh and dry biomass of both spinach and broccoli plant yields were, however, greatest with high soy treatment followed by high mustard meal treatment. Among the nutrient accumulation, plant Se, calcium (Ca), manganese (Mn), and zinc (Zn) consistently increased in spinach leaves and in broccoli florets with high mustard meal treatments. Amending soils with Brassica seed meals have practical viability for use in organic agriculture as a potential bioherbicide and as a green fertilizer for promoting Se and other nutrient content.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: **Response of Two Tomato Varieties to Different Water Stress Levels**

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ABSTRACT:

This field study was conducted in the inland region of the California Central Coast, to compare the impact of five water stress levels (100%, 75%, 50%, 25%, and 0% of CIMIS) on two organically grown tomato varieties, "Early Girl" (EG) and Brandy Wine ("BW"). Initially, all plots were equally irrigated until initial bloom stage when the different treatments were imposed. Plant canopy showed subtle impact of water stress on foliage as indicated by slight greening of foliage. Yield data indicated no significant differences EG, while "BW" showed a 50% decrease in economic yield. Fruit size however, showed more complicated trends. Across irrigation treatments, "Brandy Wine" produced 87 to 97% of its fruit in the extra large category. On the other hand, "EG" fruit size did not follow a linear trend.
Fruit dry matter and soluble solids were highest at treatments 0% and 12% for "BW" and under extreme water stress in "EG". Fruit color of "EG" was less affected by treatments while treatments 12% and 25% resulted in lighter color "BW" fruit.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: **Soil CO2 Respiration as an Index of C and N-Mineralization**
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ABSTRACT:

It is increasingly necessary to assess soil N-mineralization potential as a means to reduce excessive N-fertilization leading to surface and groundwater nutrient contamination. It is also important to better evaluate soil carbon turnover in order to manage soils in their important climate CO2 exchange role. Soil laboratory test methods to measure carbon and nitrogen mineralization vary considerably and yet the equipment and labor required to perform accurate tests have limited widespread adoption. Very few soil labs which routinely recommended nutrients also employ lab methods for natural soil nutrient supply capability. A new commercial soil kit called Solvita® is now available to rapidly measure CO2-burst in a drying-wetting protocol. We compared this method to existing CO2 respiration lab tests (alkali-trap, IRGA) and found all to be highly correlated. We further compared N potential from PSNT and 7d anaerobic tests with good correlation. PSNT provides Yes/No decisions for N-fertilization but may overestimate the need when soils are leached. 7-day N-min correlated well but is time consuming and activates facultative anaerobic organisms although soils are generally aerobic. We evaluated soils receiving varying rates of manure and observed a linear CO2 response to application rate. A close relationship with biomass was observed (fumigation SMBC). The trials overall suggest that the Solvita system for soil CO2 response is may be easily and accurately used to estimate biomass, microbial activity and potential mineralizable N. The widespread adoption by labs of a more rapid procedure which is also cost effective for commercial soil labs could greatly improve N-rate recommendations, potentially reduce excessive N-fertilization, and significantly increase appreciation by growers and the public for soils vital role in nutrient and climate CO2 exchange.

POSTER SUBMISSSION: PROFESSIONAL

Title of Paper: **Evaluation of Deficit Irrigation of Blackeye Cowpeas Under Variable Plant Densities.**

Author(s): Carol Frate, University of California Cooperative Extension, Tulare, CA; Shannon Mueller, UC Cooperative Extension, Fresno, CA; Lawrence Schwankl, Dept. of LAWR, UC Davis, Kearney Agricultural Center, Parlier, CA; Blake Sanden, UC Cooperative Extension, Bakersfield, CA; Pete G. Goodell, UC Cooperative Extension, Parlier, CA; Jeffrey Ehlers, Dept Botany and Plant Science, UC-Riverside, Riverside, CA; and Steven Temple, Dept. of Plant Sciences, UC-Davis, Davis, CA

ABSTRACT:

Blackeye cowpeas are the main dry bean type grown in the southern portion of California's San Joaquin Valley. All of the acreage is produced under furrow irrigation. The cost and, in some years the availability of water, are issues facing growers. Two trials, conducted in 2009, evaluated the impact of different irrigation regimes on the yield and quality of two blackeye varieties, CB 46 and CB 50, planted at three populations. One trial was at the University of California Kearney Research and Education Center and the other at the U.C. Shafter Research and Education Center. The irrigation regimes included the conventional treatment with irrigation every 7 to 10 days, alternate furrow treatment with irrigation timing the same as the conventional treatment but with water only in every other furrow, and the extended treatment which was irrigated in every furrow at 14 to 20 day intervals. The experimental design was a split-split plot in both locations with irrigation as the main treatment, variety as the first split and three plant populations as the split on variety. Soil moisture was monitored in one location with soil moisture blocks and in the other trial with a neutron probe. The center rows of each plot were cut and allowed to dry before threshing. Yields in the alternate and extended treatments were significantly reduced compared to the conventional treatment. Bean size was also reduced in the alternate and extended treatments compared to the conventional treatment. There were no significant differences in yield between the two varieties but CB50 had larger beans. The highest plant population, approximately 6 plants per foot, produced significantly higher yields in all three irrigation regimes at the Shafter location compared to the 4 and 6 inch spacing. In the Kearney location, there was an interaction between irrigation treatment, varieties and plant populations. (Originally presented Nov. 2, 2010, ASA-CSSA-SSSA Meetings, Long Beach, CA)

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: **Influences of Winter Cover Crops and Irrigation Systems on Tomato Growth and Water Use**

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ABSTRACT:

The use of groundwater for crop irrigation in California increases because of the shortage of surface water, which may be exacerbated in the long-term due to climate change. Management practices that decrease water losses from cropland and increase irrigation efficiency may provide good solutions. This study evaluated the effects of three winter cover crop treatments (fallow, triticale, and mixture of bell bean and vetch) and two irrigation practices (subsurface drip-SDI and furrow irrigation-FI) on tomato growth and water use. We found that total water applied for FI was in the order of mixture > triticale > fallow. This was mainly due to faster flow rates were required for plots following the two cover crop treatments than following winter fallow when the speed of water advancing in the furrows was kept the same for each irrigation event. Water applied under subsurface drip irrigation was based on canopy cover and not different among cover crop treatments. Tomato plants had greater canopy cover under SDI than FI. Leaf stomatal conductance was inconclusive in the early growing season but reduced for plants under FI following winter fallow. Marketable tomato yield was in the order of mixture and triticale treatments under both irrigation systems > winter fallow under SDI > winter fallow under FI. For furrow irrigation, tomato yield was positively related to total water received by a linear function. For drip irrigation where there was no difference in total irrigated water, tomato yielded less following winter fallow.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: **Irrigation Management using High TDS Waters for Processing Tomatoes**

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ABSTRACT:

The proportion of processing tomato acreage irrigated using subsurface drip irrigation (SDI) has ballooned over recent years with more than 90 percent of the western San Joaquin valley crop adopting this method. And as growers in the region increasingly move to well water to supplement or exclusively supply crop water needs, they are at greater risk to experience long term salt buildup that reduces future soil quality and crop yield. Trials were conducted during the 2010 season to evaluate the use of high TDS well water on processing tomatoes using three contrasting irrigation regimes. This year's results demonstrate that under carefully controlled field scale conditions, irrigation and salinity management can play a significant role in generating high yields and product quality can be controlled though judicious irrigation scheduling. Although no differences were observed in crop yield, changes in processing tomato quality were observed between all 3 established irrigation treatments that were consistent with previous research work. Controlled deficit irrigation management may have a permanent role in the processing tomato industry however questions of long-term salt balance need to be addressed.

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California Chapter – American Society of Agronomy
2011 Plant and Soil Conference Evaluation

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Please complete and return this form to the registration desk or drop it in the provided boxes. Thank you for your assistance in completing this survey. Your responses will help us improve future Chapter activities.

1. Conference Evaluation

	Agree			Disagree	
Conference fulfilled my expectations	1	2	3	4	5
Conference provided useful information	1	2	3	4	5
Conference provided good contacts	1	2	3	4	5

2. What session topics do you recommend for future conferences?

a. ____

b. ____

3. Please suggest Chapter members who would be an asset to the Chapter as Board members.

a. ____

b. ____

4. Who would you suggest the Chapter honor in future years? The person should be nearing the end of their career. Please provide their name, a brief statement regarding their contribution to California agriculture, and the name of a person who could tell us more about your proposed honoree.

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5 Please rank your preference for the location of next year's conference. (Use 1 for first choice, 2 for second, etc.)

____ Fresno ____ Visalia ____ Modesto ____ Sacramento ____ Bakersfield

____ Other (please provide) ____

6. Would having the speakers' Powerpoint presentations, available on the CA ASA website after the Conference, be an acceptable alternative to the written Proceedings?

______ Yes ______ No

7. Additional comments:____

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