



American Society of Agronomy

California Chapter

Co-sponsored by the California Plant Health Association

2012

**CONFERENCE
PROCEEDINGS**

*Regulatory Issues Impacting
California Agriculture*

February 7 & 8, 2012

**Holiday Inn
Visalia, CA**

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2012 CALIFORNIA PLANT AND SOIL CONFERENCE
REGULATORY ISSUES IMPACTING CALIFORNIA AGRICULTURE

TUESDAY, FEBRUARY 7, 2012

- 10:00 **General Session Introduction** – Session Chair & Chapter President – Mary Bianchi, UC Cooperative Extension
10:10 Land Use Planning and Prosperous Agriculture - Holly King, Castle Rock Farms, LLC
10:40 2012 Water Supplies: Conditions and Issues - Sarge Green, CSU–Fresno, Center Irrigation Technology
11:10 Water Regulations in California – Loren Harlow, Stoel Rives, LLP
11:40 Discussion

12:00 LUNCH – Opportunity to Network with Colleagues and Friends

CONCURRENT SESSIONS (PM)

- | I. Nutrient Management | II. Environmental Regulations |
|--|--|
| 1:30 Introduction – Session Chairs, Rich Rosecrance, CSU-Chico and Danyal Kasapligil, Dellavalle Laboratory, Fresno, CA | 1:30 Introduction – Session Chairs, Rodrigo Krugner, USDA-ARS, Parlier, Mary Bianchi, UC Cooperative Extension, SLO, and Matt Fossen, DPR, Sacramento |
| 1:35 Development of Leaf Sampling and Interpretation Methods for Almonds, Sabastian Saa Silva, Department of Plant Sciences, UC Davis | 1:35 How Do Regulations Become Reality? David Ceppos, Center for Collaborative Policy, CSU-Sacramento |
| 2:00 How to Improve N Use Efficiency in Fruit and Nut Crops without Government Regulation, Scott Johnson, Kearney Agricultural Center, Parlier, CA | 2:00 Key Agricultural Labor Regulations. Manuel Cunha Jr., President Nisei Farmers League |
| 2:25 Improving N Use Efficiency in Intensive Vegetable Production, Richard Smith, UC Cooperative Extension, Monterey County | 2:25 Status of Air Quality Regulations for Agriculture. Roger Isom, President, California Cotton Ginners and Growers Association |
| 2:50 Discussion | 2:50 Discussion |
| 3:00 BREAK | 3:00 BREAK |
| 3:20 Insights from the California Nitrogen Assessment, Sonja Brodt, Sustainable Agricultural Research and Education Program, UC Davis | 3:20 Impact of Air and Water Quality Regulations or Requirements on Dairy Management, Deanne Meyer, Livestock Waste Management Specialist, UC Davis |
| 3:45 Soil and Plant Nutrient Analyses – Perspective from the Field, Keith Backman, Dellavalle Laboratory, Fresno, CA | 3:45 Local Climate Action Plans: How Input from Agricultural Stakeholders Adds Value to Mitigation and Adaptation Efforts. Ryan Hayden, Department of Land, Air, and Water Resources, UC Davis |
| 4:10 Estimating Plant-available K in K-fixing Soils, Gordon Rees, Department of Land, Air, and Water Resources, UC Davis | 4:10 A Department of Pesticide Regulation Update, Matt Fossen, DPR, Sacramento, CA |
| 4:35 Discussion | 4:35 Discussion |
| 4:45 Adjourn | 4:45 Adjourn |

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

III. Water Management

- 8:30** **Introduction** – Session Chairs, Florence Cassel-Sharma, CSU-Fresno, Larry Schwankl, UC Kearney Agricultural Center, and Allan Fulton, UC Cooperative Extension, Tehama County
- 8:35 Optimizing Drip Irrigation Systems for Seed Alfalfa in the Central San Joaquin Valley. Shannon Mueller, UC Cooperative Extension, Fresno County
- 9:00 Subsurface Drip Irrigation in Alfalfa Hay, Khalid Bali, UC Cooperative Extension, Imperial County
- 9:25 Improving Water and Nitrogen Efficiency in Lettuce, Michael Cahn, UC Cooperative Extension, Monterey County
- 9:50 Discussion
- 10:00 BREAK**
- 10:20 Influence of Regulated Deficit Irrigation Strategies Applied to 'Arbequina' Olive Trees On Oil Yield and Oil Composition, Rich Rosecrance, CSU-Chico.
- 10:45 New Insights to Water Management in Almonds, Blake Sanden, UC Cooperative Extension, Tehama County
- 11:10 Using EM and VERIS technology to Assess Land Suitability for Orchard Development, Allan Fulton, UC Cooperative Extension, Tehama County
- 11:35 Discussion
- 11:50 Adjourn**

IV. Pests n' Pollinators

- 8:30** **Introduction** – Session Chairs, Carol Frate, UC Cooperative Extension, Tulare County, Rodrigo Krugner, USDA-ARS, Parlier, and Brad Hanson, UC Davis
- 8:35 Overview of Current Quarantines and Management of Citrus Pests in California, Ray Yokomi, USDA-ARS, Parlier
- 9:00 Commodity Export Treatment Requirements and Regulations, John Lloyd, USDA-APHIS, Fresno
- 9:25 Postharvest Fumigation of Specialty Crops, Spenser Walse, USDA-ARS, Parlier
- 9:50 Discussion
- 10:00 BREAK**
- 10:20 Importance of the Honey Bee Pollination Industry and Threats to its Sustainability, Gordon Wardell, Paramount Farming
- 10:45 Pesticide Issues and Honey Bees: A California Perspective, Rich Bireley, DPR, Sacramento
- 11:10 Development of wildflower mixes to promote native pollinators in agriculture, Neal Williams, Department of Entomology, UC Davis
- 11:35 Discussion
- 11:50 Adjourn**

12:00

ANNUAL CHAPTER BUSINESS MEETING LUNCHEON

Presentation of Honorees, scholarship awards, and election of officers

CONCURRENT SESSIONS (PM)

V. Dairy Issues

- 1:30** **Introduction** – Session Chairs – Nathan Heeringa, Innovative Ag Services and Larry Schwankl, UC Kearney Agricultural Center
- 1:35 Nutrient Management on California Dairies: How to Help Your Clients, Deanne Meyer, Livestock Waste Management Specialist, UC Davis
- 2:00 Salinity and Dairies in the Central Valley: Long-term Prospects for Salt Management, Dennis Westcott, Project Administrator, San Joaquin River Group Authority, Davis, CA
- 2:25 Proper Design of Dairy Liquid Manure Distribution Systems to Facilitate Agronomic Applications, Micah Bowman, Provost and Pritchard Consulting Group
- 2:50 A Review of the Central Valley Dairy Representative Monitoring Program, Till Angermann, Luhdorff & Scalmanini Consulting Engineers, Woodland, CA
- 3:15 Discussion
- 3:30 ADJOURN**

VI. BMP's for Carbon and Nutrient Dynamics

- 1:30** **Introduction** – Toby O'Geen, UC Davis and Dave Goorahoo, CSU-Fresno
- 1:35 Synchronizing Soil Biology with BMP's: The Future of Carbon and Nutrient Management, Bruce Roberts, CSU-Fresno
- 2:00 Nitrous Oxide Emissions from Selected Corn and Cotton Cropping Systems, Dave Goorahoo, CSU-Fresno
- 2:25 The Role of Constructed Wetlands in Agriculture, Toby O'Geen, Department of Land, Air, and Water Resources, UC Davis
- 2:50 Investigating Potential Benefits of Soil Biochar Amendments. Sanjai J. Parikh, Department of Land, Air, Water Resources, UC Davis
- 3:15 Discussion
- 3:30 ADJOURN**

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PAST PRESIDENTS

| YEAR | PRESIDENT | YEAR | PRESIDENT |
|------|----------------------|------|----------------|
| 1972 | Duane S. Mikkelsen | 2010 | Larry Schwankl |
| 1973 | Iver Johnson | 2011 | Mary Bianchi |
| 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. Bronson | | |
| 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 Zodolske | | |
| 2004 | Casey Walsh Cady | | |
| 2005 | Ronald Brase | | |
| 2006 | Bruce Roberts | | |
| 2007 | Will Horwath | | |
| 2008 | Ben Nydam | | |
| 2009 | Tom Babb | | |

PAST HONOREES

| YEAR | HONOREE | YEAR | HONOREE | YEAR | HONOREE |
|------|------------------------|------|-----------------------|------|----------------------|
| 1973 | J. Earl Coke | 1995 | Leslie K. Stromberg | 2007 | Norman McGillivray |
| 1974 | W.B. Camp | | Jack Stone | | William Pruitt |
| 1975 | Ichiro "Ike" Kawaguchi | 1996 | Henry Voss | | J.D. Oster |
| 1976 | Malcom H. McVickar | | Audy Bell | 2008 | V.T. Walhood |
| | Perry R. Stout | 1997 | Jolly Batcheller | | Vern Marble |
| 1977 | Henry A. Jones | | Hubert B. Cooper, Jr. | | Catherine M. Grieve |
| 1978 | Warren E. Schoonover | | Joseph Smith | 2009 | Dennis Westcot |
| 1979 | R. Earl Storie | 1998 | Bill Isom | | Roland Meyer |
| 1980 | Bertil A. Krantz | | George Johannessen | | Nat Dellavalle |
| 1981 | R.L. "Lucky" Luckhardt | 1999 | Bill Fisher | 2010 | L. Peter Christensen |
| 1982 | R. Merton Love | | Bob Ball | | D. William Rains |
| 1983 | Paul F. Knowles | | Owen Rice | 2011 | Blaine Hanson |
| | Iver Johnson | 2000 | Don Grimes | | Gene Maas |
| 1984 | Hans Jenny | | Claude Phene | | Michael Singer |
| | George R. Hawkes | | A.E. "Al" Ludwick | 2012 | Bob Matchett |
| 1985 | Albert Ulrich | 2001 | Cal Qualset | | Don May |
| 1986 | Robert M. Hagan | | James R. Rhoades | | Terry Prichard |
| 1987 | Oscar A. Lorenz | 2002 | Emmanuel Epstein | | |
| 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 Merriam | 2006 | John Letey, Jr. | | |
| 1994 | George V. Ferry | | Joseph B. Summers | | |
| | John H. Turner | | | | |
| | James T. Thorup | | | | |



2011 Chapter Board Members

Executive Committee

| | |
|-----------------------|---|
| President | Mary Bianchi, UCCE San Luis Obispo County |
| First Vice President | Allan Fulton, UCCE Tehama County |
| Second Vice President | Dave Goorahoo, CSU-Fresno |
| Secretary-Treasurer | Steve Grattan, UC Davis |
| Past President | Larry Schwankl, UC Davis |

Governing Board Members

| | |
|-----------------|--|
| One-year Term | Carol Frate, UCCE Tulare County Brad Hanson, UC Davis Nathan Heeringa, Innovative Ag Services, LLC |
| Two-year Term | Matt Fossen, CA Depart. of Pesticide Regulation Rodrigo Krugner, USDA-ARS Danyal Kasapligil, Dellavalle Laboratory |
| Three-year Term | Florence Cassel-Sharma, CSU-Fresno Toby O'Geen, UC Davis Rich Rosecrance, CSU-Chico |

**CALIFORNIA CHAPTER – AMERICAN SOCIETY OF AGRONOMY
2011 ANNUAL CHAPTER BUSINESS MEETING; February 1, 2011**

1. Call to Order, (President Larry Schwankl at 12:30 pm)

- a. Welcomed attendees to the 39th annual meeting of the Calif. Chapter of the ASA; Highlighted that the society meetings begun in 1972 and is one of the longest running conferences and is consistently attended in CA.; It is one of the few conferences where you receive proceeding when you register; and you now have Conference Proceedings on the Chapter's web site.
- b. Acknowledged that like 2010, the conference is again being conducted in cooperation with California Certified Crop Advisers (CCA).
- c. Student attendees were acknowledged, and asked to stand and be recognized.
- d. Acknowledged and thanked the sponsors for refreshments for the breaks:
 - o Buttonwillow Warehouse Company (BWC)
 - o Valley Tech Agricultural Laboratory Services
- e. Introduced the Executive Committee and Governing Board and thanked everyone for the hard work & preparing yet another great Plant & Soil Conference, with the acknowledgment that all positions were volunteered:
 - o Past President, Joe Fabry (Honorees);
 - o 1st VP, Mary Bianchi (Proceedings);
 - o 2nd VP, Allan Fulton (Site Arrangements);
 - o Secretary & Treasurer, Dave Goorahoo (Registration);
 - o Governing board: Sharon Benes, Lori Berger, Brook Gale, Nathan Heeringa, Brad Hanson, Steve Grattan, Danyal Kasapligil, Matt Fossen, and Rodrigo Krugner
- f. Introduced and thanked *Past Presidents* and any *individuals who served* on the Governing Board of the Chapter.

2. Presented minutes of Business Meeting of Feb 2010 (Introduction Schwankl)

- a. Indicated that the Minutes of Feb 3, 2010 business meeting were in the proceedings.
- b. There were no corrections or additions. Motion to approve, seconded and passed.

3. Treasurer's Report (Introduction- Schwankl)

- a. Presented Treasurer's report for the 2010 calendar year (Goorahoo)
- b. Approval of Treasurer's Report (Schwankl) moved, seconded and passed.

4. Nomination & Election of persons to serve on the Governing Board (Schwankl)

- a. Explanation of structure: 9 persons serving 3 year terms; diverse disciplines; diverse organizational relationships; this diversity in board members is required by our Chapter By-Laws and is one of the reasons that we always have a well balanced conference.
- b. Rotating off the Board after their 3-year terms as well as past president were acknowledged and thanked for their dedication and hard work.
- c. Nominations opened for the election of persons to serve on the 2011 Governing Board.
- d. Board nominations for the Executive Committee and Governing Board were presented:
 - i) Mary Bianchi as President
 - ii) Allan Fulton as First Vice President
 - iii) Dave Goorahoo as 2nd Vice President

- iv) Steve Grattan as Secretary/Treasurer
- v) Carol Frate 1 year term – filling out Steve Grattan’s term
- vi) To serve for 3 Year Terms:
 - 1. Toby O’Geen, UC Davis
 - 2. Rich Rosecrance, Chico State
 - 3. Florence Cassel, Fresno State
- e. There were no other nominations from the floor.
- f. Motion, seconded and passed to accept the unanimously the Board Nominations.

5. Honorees Program

- a. Introduction (Joe Fabry). Attendees were referred to the brief biography of each honoree in the proceedings.
- b. Individual presentations:
 - i) Mike Singer (presented by Will Horwath)
 - ii) Blaine Hanson, (presented by Larry Schwankl)
 - iii) Gene Maas (presented by Steve Grattan)

6. Scholarship Recognition (Introduction- Schwankl)

- a. Recognized committee: Brad Hanson; Rodrigo Krugner, Sharon Benes, and Carol Frate.
- b. Acknowledged support of Western Plant Health Association, \$1,500 donation. Schwankl introduced Keith Backman, who presented the winners with their prizes (\$700 each):
 - o Sonia Rios, California State Polytechnic University Pomona;
 - o Elizabeth Reese - University of California Davis; and,
 - o Analisse Scrivano – California Polytechnic State University San Luis Obispo.

7. Poster Awards – (Introduction-Rodrigo Krugner)

- o 1st place Graduate Student, \$300, Nathalia Mourad, CSU-Fresno
- o 2nd place Graduate Student, \$200, Prasad Yadavali, CSU-Fresno
- o 3rd place Graduate Student, \$100, Eeshan Mokashi, CSU- Fresno
- o 1st place Undergraduate Student, \$300, Annabel Rodriguez, CSU-Fresno

8. Old Business – No old business was discussed.

9. New Business- No new business was discussed.

10. Conference Evaluation Forms (Schwankl)

Attendees were reminded that it was important to fill in the forms with suggestions for: topics, locations, suggestions for honorees, and their interests in serving as a board member.

11. Passing of the Gavel (Schwankl/Bianchi)

- a. Mary Bianchi presented with the official Chapter Gavel; Bianchi assumed her duties as Chapter President.
- b. Bianchi presented Schwankl with a plaque in appreciation for his service to the Chapter.

12. Meeting Adjournment (Bianchi) in time for afternoon sessions that began at 1:30 PM.



American Society of Agronomy

California Chapter

2012 Honorees

Robert “Bob” Matchett

Don May

Terry Prichard

Robert W. Matchett

Cereal grain breeder

Bob Matchett was raised in the Sacramento Valley and showed an early interest in agriculture through his activities in FFA at the high school level. As a member of the Agronomy seed judging team at Yuba City High School, he had the good fortune to meet Dr. Dale Smeltzer at the UCD Agronomy Department. Dale recommended that Bob come to Davis and major in Agronomy. That fortuitous contact did much to determine the educational path that would lead Bob into the plant breeding profession. He received his B.S. degree in 1964 and M.S. in 1966 with major professor Dr. Caswell Williams. Bob's research introduced him to stripe rust which would be at the center of most of his future plant breeding efforts. He received his PhD at Colorado State University in 1968, as the last graduate student of Dr. D.W. "Scotty" Robertson, a noted barley geneticist. Bob's barley research led to two scientific publications.

Bob took a barley breeding position with Northrup, King Co. in 1968, at Woodland, California. Through the 1970's, Bob released four high-yield, semi-dwarf barley varieties for California. In the 1980's, Bob's efforts moved to an emphasis on wheat and triticale breeding. Four hard red spring wheats were released from the NK California program during the years when significant seed sales were being made to Saudi Arabia. In 1987, Northrup, King terminated the California cereal breeding program.

In 1988, Bob and his long time assistant Oly Cantu (40 years of partnership) were hired by Goldsmith Flower Seed Co. to carry out a triticale breeding program. The objective of this program was to boost grain production in Kenya where Goldsmith had flower seed production operations and also to increase feed grain yields in California. To enhance the success of the breeding effort, Bob and Oly decided to continue their work on both wheat and triticale. They were able to cobble together a program that became Resource Seeds, Inc. This program released fifteen bread wheat, three durum and eight triticale varieties for use by California growers. A significant accomplishment was the transformation of tall, lodging-prone triticale genotypes to high yield, semi-dwarfs that were often mistaken for bread wheats until the surprising grain yields were calculated, revealing the superiority of the triticales. The RSI program also released three hard red and two hard white spring wheat varieties plus four triticale varieties in the Pacific Northwest. Two varieties of forage and grain-type triticales were released in the South Eastern part of the U.S. The success enjoyed by RSI's cereal grain breeding program was due to a strong team effort. Bob, Oly, and Anneth Angel worked through forty acres of field nurseries each year in order to find the perfect plant.

"I have greatly enjoyed my forty-two years as a plant breeder located in the most diverse agricultural state in the nation. I always looked forward each winter to getting back into the field in April to initiate the breeding program anew. I relished the mental and physical challenge that came with trying to create the very best plant varieties in a very competitive industry. I have been very fortunate to have been able to be in the profession I chose for my life's work with so many colleagues and friends who made that work most enjoyable."

Don May

UC Cooperative Extension Farm Advisor Emeritus

Don May was raised on an alfalfa and livestock farm in Utah. He belonged to both 4-H and FFA and showed beef, sheep and hogs at the county fair. All his life had been engaged in agricultural related work. He married Peggy Wright, his home town sweetheart from the farm community of Delta, Utah.

Don received a BS in 1957 and MS in 1958 in agronomy at Utah State University. He was then employed by the University of California Cooperation Extension in 1958 as an agronomist Farm Advisor and retired after 52 enjoyable years as a UC farm advisor.

After 7 years in LA County as agronomist, he was chosen in 1965 to become the first full time Fresno County Vegetable Crop Farm Advisor on the basis of his strong research program in LA. and his introduction of new agronomy crops to the farmers of the Antelope Valley.

Because of the increase in vegetable crop production in Fresno County, Don's research focus was on profitable and sustainable vegetable crop production. The major crops were processing tomatoes, melons, onions and garlic. Developing good varieties of tomatoes for hot temperatures was major focus of his extensive trials, which had a major impact.

Over time, the tomato production acreage south of Merced County increased to 70% of the statewide production, and at the same time, tomato yields increased 2-3 fold with about the same amount of fertilizer and water. Don's program helped farmers find better tools to manage their resources by conducting a large number of applied research trials on tomato nutrition and drip irrigation of processing tomatoes at the University of California West Side Research and Extension Center and on leading farmers' fields. Research results were then disseminated through meetings and a quarterly newsletter.

Other major projects in early '70's research changed the melon packing system from 80# wood crates to 40# paper cartons, which substantially reduced costs. Don introduced the use of virus free sweet potatoes and garlic seed to growers that doubled yields and improved fruit quality. He contributed in the development of plant tissue nutrient levels of vegetable crops used by commercial labs to advise farmers. He was heavily involved in the Integrated Pest Management from its beginning and promoted practices that changed the growers pesticide use to treat only when necessary, not to a schedule. This led to greatly reduced pesticide use. His research at the WSFS from 1970 -1990 developed the processing tomato irrigation scheduling program to maximize yield and percent solids which is used world- wide for both furrow and drip irrigation.

Don has published 95 peer reviewed papers. Awards include: 1990 - Distinguished Service Award from Fresno Farm Bureau (as Farmer of the Year) for 25 years of service to Fresno County Vegetable industry; 1994 - Served as a member of the American Horticulture Society Cooperative Extension Research Committee; 1996 - Recognized by the 2nd world wide Congress on Processing Tomato for publishing the most scientific papers since their inception in 1989; 2004 - Appreciation award for many years of outstanding contributions to the California melon

industry by California Melon Research Board; 2009 - Recognition award from the California Tomato Processing Growers Association for research on drip irrigation.

“I have enjoyed the challenges for 52 years of conducting applied research and education of agronomy, the first 7 years as an agronomist, 37 years as a Vegetable Crops Farm Advisor, and 8 years as an associate researcher on water issues with Blaine Hanson. I am grateful to have been in the best place at the right time to associate with many outstanding people and friends in both the University of California and the agricultural industry and their support of my research and extension program. I am most happy I chose to work with plants instead of animals because I have never been kicked by a tomato.”

Terry Prichard
CE Water Management Specialist, Emeritus

Terry was raised on a dairy in Stanislaus County where he participated in 4-H and FFA activities and projects in dairy, beef, sheep and poultry. Projects in high school culminated in a 250 laying hen project combined with a home egg delivery service. While in FFA he participated in soil judging contests at a number of colleges with an eye out for the best one to attend. After a couple of years at Modesto Junior College, then a few more at Cal Poly in soil science, it was off to UC Davis to study soils and plant nutrition with Emanuel Epstein in the Department of Soils and Plant Nutrition (pre-LAWR days). He married Fay Williams, also from Oakdale, in 1970. They have two children, Nick a civil engineer living in Oakdale, and Lauren a CPA living in San Diego.

While in Hoagland Hall at UC Davis, working on the department's only computer outside of CE Specialist Roy Rauschkolb's office, Roy asked, "What do you really want to do." The answer was to be a soil and crop Farm Advisor working with growers to optimize resource inputs. Roy suggested applying for a position in San Joaquin County where they were looking for a field crops Farm Advisor with a soils and water specialty. Terry started with UC Cooperative Extension in Stockton in 1975 as a Farm Advisor, then in 1978 changing to Area Soils and Water Specialist, then in the mid eighties to a Water Management Specialist in the UCD Department of Land, Air & Water Resources (LAWR).

Research interests were centered on plant stress- either from salts or lack of water. Notable research projects include determining the salt tolerance of corn in organic soils and understanding salt leaching dynamics in organic soils with high water tables and the costs associated with leaching practices. Water relations of almond, walnut, and wine grapes were investigated in long-term studies that supported his water management outreach program. In the last few years, a significant portion of his time was devoted to encouraging growers to adopt management practices that reduce offsite movement of agricultural chemicals.

"I have enjoyed the 35 years of extension activities. Interaction with the agricultural community, especially working with growers, has been the most rewarding. I have had the great fortune to work with truly dedicated friends and colleagues of the highest standards. Now it is my turn to implement some of the management practices that I worked on over the years – on our family farm."



American Society of Agronomy

California Chapter

2012 Scholarship Recipients & Essays

Essay Question:

How can California's agricultural industries contribute to and benefit from state and federal "green energy" initiatives?"

Scholarship Committee:

Brad Hanson, Chair
Rodrigo Krugner
Sharon Benes
Carol Frate

2012 Scholarship Award Winners

Stacey Haack, University of California - Davis

A synergy of efforts from multiple fronts—this is the key necessity for moving California agricultural industries toward a future of integrative energy sustainability. Federal and state green initiatives serve to encourage the large scale conversation between researchers and industry applications; facilitating an increase in confidence and education needed to apply ideas from lab to field. This helps to achieve short and long-term energy goals for the good of the industry and for the environment, giving agriculture the push it needs in the inevitable direction. Through the green energy initiatives, methods of prevention, efficiency, and ecosystem integration ideas also come together to show how agriculture can climb the ranks as an energy conscious and efficient industry—now and in the future.

Preventative practices in agriculture can help to achieve both short and long term energy goals. On the short term, integrated pest management systems help to reduce pesticide spray frequencies and employ biological control of pests. In the future, traditional breeding programs can be seen as vectors of innovation in within-plant resistance to fungal, viral, and insecticidal pests that currently motivate agricultural systems to use pesticides. Each of these methods reduce the amount of energy needed to produce, transport, and apply pesticides, not to mention reducing the release of these chemicals into the environment.

Increases in efficiency of water and nutrient management also serves as a platform upon which California agriculture can contribute to energy initiatives. Current research on actual water and nutrient needs, as well as proper methods of analyzing current plant status—when put into application through energy initiatives and education—can help to more precisely manage these valuable resources. Once again, traditional breeding of lines that have increased drought tolerance and increased nutrient uptake efficiency also prove promising. Each of these methods help to reduce net usage of nutrients and water that is energetically expensive to produce/filter and transport. Furthermore, increased efficiency reduces water waste and loss/contamination of nutrients in California waterways.

Green energy initiatives also encourage innovative thinking of agriculture as an entire ecosystem. There are many ideas for methods of integrating agriculture into a full circle system—with inputs equaling outputs, and therefore balancing energetically—without a cost to the economic stability of the agricultural industry. Ideas such as the use of runoff in specialized detoxification wetlands environments adjacent to fields, as well as recovery and recycling of agricultural waste, show the potential for agriculture's contribution to whole-system energy efficiency in the future.

Green energy initiatives facilitate the progression of each of these methods through which agriculture can contribute to a greener future. Without the funding and support of applied research, realistic application, and appropriate regulation that green initiatives provide, the agricultural industry would be without the great benefit and power of the synergy that now surrounds the industry. With the efforts of so many to improve energy efficiency in California agriculture, combined with the innate potential agriculture has to be a lead industry in energy efficiency, the future of California agriculture is bright.

Luke Milliron, California State University – Chico

In any biological system such as farming, change is inevitable. Inevitable change is a theme that will be at the heart of California agriculture throughout the 21st Century. These changes will not only come from Sacramento and Washington D.C., but be dictated by an ever changing California climate, and the annual budgets of California farmers. The great challenge in 21st Century California agriculture will be a choice of perception. The challenge will be to view these inevitable changes not as a burden, but as opportunity.

Federal and state initiatives in green energy and energy efficiency lead the way in designing programs that will be practical for California agriculture stakeholders. At a federal level the USDA has greatly encouraged the adoption of green energy, whether it be solar, wind, hydroenergy, geothermal as well as bioenergy and biofuels. The Rural Energy for America Program (REAP) aims to fund projects nationwide that reduce energy consumption, utilize renewable energy sources, or conduct feasibility studies that analyze the efficacy of green energy projects. At the state level the California Energy Commission's Energy in Agriculture Program aims to encourage the adoption of energy-efficient technology, and sustainable management practices in dairy and livestock, field equipment, food processing, on-farm irrigation and irrigation districts.

The University of California Cooperative Extension, the University's land-grant institutions, and the agricultural researchers within the California State University system work to bring cutting edge energy efficiency practices to California farmers. Research surrounding best management practices includes the sustainable management of biosolids on California dairies, the adoption of subsurface drip irrigation in field crops, and increasing nitrogen use efficiency in vegetable production. With considerable support from the USDA, the California Energy Commission, UCCE and California's agricultural universities, I believe California farmers not only will be able to keep up with the challenges of the 21st Century, but be at the forefront of green energy and energy efficiency.

Sonia Rios, California State Polytechnic University - Pomona

California is the nation's leader in agricultural innovation, technology, and production. California's agricultural industries lead in energy efficiency and conservation, sustainability, green building and green purchasing practices. The federal and state government has a number of comprehensive and pro-active public health, safety, and environmental protection programs that make California's agricultural industry a contributor to and beneficiary of "green energy" initiatives. California's agriculture industry has currently been benefiting from initiatives such as the California Solar Initiative, grant money from the U.S. Department of Energy and the Wind Powering America Initiative.

The California Solar Initiative is a solar rebate program for California customers of the investor-owned utilities which include; Pacific Gas and Electric, Southern California Edison, and San Diego Gas & Electric. California Solar Initiative customers earn cash rebates for every watt of solar energy installed on their homes, businesses, farms, and government and non-profit organizations. This program funds both solar photovoltaics (PV), as well as other solar thermal generating technologies. An example of how a similar type of initiative works that is currently in place involves the Stone Land Company located in Lemoore, CA. The environmentally friendly company installed a solar tracking system to leverage existing non-farm land and reduce operating costs. The solar panels generate power corresponding with peak demand, when energy is most expensive.

Initiatives also come in the form of grants. Director of the U.C. Kearney Research and Extension Center, Jeff Dahlberg, is the lead investigator on a \$984,000 U.S. Department of Energy grant to study the composition of sorghum and its potential for cellulosic conversion to biofuel. According to the U.S. Energy Information Administration, U.S. ethanol production in January, 2010, was at 818,000 barrels per day compared to its use of approximately 20 million barrels of oil per day. Cellulosic biomass is the only known resource for the sustainable production of liquid transportation. Since a dry ton of cellulosic biomass could provide about three times as much energy as a barrel of petroleum, the cellulosic biomass would have three times the value as a barrel of oil.

In addition, the U.S. Department of Energy's "Wind Powering America" initiative has set a goal of producing five percent of the nation's electricity from wind by 2020. Wind generated electricity reduces the use of fossil fuels and assists in reducing our impact on natural resources. Growers are in a distinctive position to benefit from the growth of the wind industry. Growers can lease land to wind developers, use the wind to generate power for their farms, or become wind power producers themselves. Large wind turbines typically use less than half an acre of land which allows farmers to continue growing crops and graze livestock right up to the base of the turbines.

California's agricultural industries continue to contribute and benefit from "green energy" initiatives. The California Solar Initiative, grants from the U.S. Department of Energy, and the Wind Powering America Initiative are just a few of the initiatives available to the agricultural industry. By implementing sustainable "green energy" practices, California can continue to minimize energy use, conserve our nation's natural resources, reduce greenhouse gas emissions, and continue to be the leader in the agricultural sector.



American Society of Agronomy

California Chapter

General Session

Regulatory Issues Impacting
California Agriculture

Session Chair:
Mary Bianchi

Land Use Planning and Prosperous Agriculture

Holly King
Castle Rock Farms, LLC
22460 Homestead Rd.
Clovis, CA 93619
(559)-269-3310
holly@triplecrown.bz

NOTES & QUESTIONS:

2012 Water Supplies: Conditions and Issues

Sarge Green
CSU–Fresno, Center Irrigation Technology
5370 N. Chestnut Ave.
Fresno, CA 93740-0018
(559) 278-2066
sgreen@csufresno.edu

NOTES & QUESTIONS:

Water Regulations in California

Loren Harlow, Stoel Rives, LLP
500 Capitol Mall, Suite 1600
Sacramento, CA 95814
(916) 319-4753 Direct
ljharlow@stoel.com

NOTES & QUESTIONS:



American Society of Agronomy

California Chapter

Session I
Nutrient Management

Session Chairs:
Danyal Kasapligil
Rich Rosecrance

Development of leaf sampling and interpretation methods for Almond

Sebastian Saa, PhD Candidate, Dept. of Plant Sciences, One Shield Avenue, Davis, CA 95616
Phone (530) 752-2588 ssaasilva@ucdavis.edu

Patrick Brown, Professor, Dept. of Plant Sciences, UC Davis. MS#2, One Shields Avenue,
Davis, CA 95616 Phone (530) 752 0929, 530 752 8502 (fax), phbrown@ucdavis.edu

Introduction

One of the simplest approaches to nutrient management and fertilization decisions is the ‘Critical Value’ concept, where fertilizers are applied to ensure that leaf nutrient concentrations exceed a previously established critical concentration associated with optimal yield levels. Ideally, critical values (CVs) are established through carefully controlled experiments in which the relationship between yield and nutrient concentration is closely followed. The majority of critical values relating to almond production, however, have been determined on the basis of visual symptoms, not from yield reduction (Beutel et al., 1978; Brown and Uriu, 1996). Yield based determination of critical values in almonds, for example, are only available for N (Uriu, 1976; Meyer, 1996; and Weinbaum et al, 1980, 1990), K (Meyer, 1996; Reidel et al, 2004) and B (Nyomora et al, 1999), and to our knowledge no yield-based CVs have been established for the essential elements P, Mg, Ca, S, Cu, Zn, Fe, Mn, Mo, Ni, or Cl.

In California the standard practice is to collect leaf samples in July, compare them to previously established standards and adjust fertilization accordingly. While leaf nutrient analysis can be used to identify deficiencies it cannot provide specific information on the appropriate fertilizer rates or timing of applications. Thus, a low analysis will indicate that current practice is inadequate, but will not indicate why or how to approach a nutrient correction.

In 2007, a majority of growers and consultants participating in the CDFA-FREP funded surveys of growers, felt that University of California CVs were not appropriate for current yield levels, they were not useful early in the season and they did not provide sufficient guidance for nutrient management. Additionally, a majority of growers commented that the current CV’s have not been established for early season fertilizer adjustments and many noted that even if a sound leaf sample is taken that the analysis cannot be used to determine a specific fertilization response. Almond trees usually bloom at the end of February and their harvest is at the end of August. The majority of the fertilization plan (50-75%) for an almond orchard is applied before mid-July. Therefore, the current leaf sampling protocol, which is in July, is too late to make in-season decisions.

This analysis suggests that current leaf sampling methodology and standards (CV’s) are inadequate as management tools, particularly given growing concern over environmental costs of excess N. Therefore, the aim of this project is to correct this situation by developing new approaches and interpretation tools that better quantify field and temporal variability that are sensitive to yield and provide for in-season monitoring, fertilizer optimization and provide specific management guidelines.

Objectives

- Determine the degree to which almond leaf nutrient status varies across a range of representative orchards and environments.
- Validate early season leaf analysis protocols and relationship with yield.
- Validate current CV's and determine if nutrient ratio analysis provides useful information to optimize fertility management.
- Develop new leaf sampling and interpretative methods for almond nutrition.

Material and Methods

A large-scale and long term survey of within-field, between-field, and between-organ nutrient concentration and variance was conducted in mature almond orchards representative of the major production regions. The interaction between yield and nutrient status is being analyzed on >400 individual trees. All almond trials have been initiated in 8 or 9 years old almond orchards of good to excellent productivity planted to nonpareil (50%).

The 4 experimental sites are located in Arbutle, Modesto, Madera, and Kern County. A cluster grid design was established in each orchard to understand nutrient and yield spatial variability. Each grid consisted in plots of 10-15 acre contiguous blocks. Leaf and nut samples from 114 trees were collected at 5 times during the season for a period of 3 years. Individual yields of these trees were also measured. Sample collection was spaced evenly over time from full leaf expansion to nut harvest. As a phenological marker, days past full bloom and stage of nut development were noted.

A standard leaf sampling protocol was used to determine nutrient concentrations in samples of exposed, non-fruiting spurs (NF), as well as leaves from fruiting spurs with 1 and 2 fruit (F1 and F2, respectively) to explore the sensitivity of different sampling methods as indicators of tree nutrient demand. To establish seasonal nutrient accumulation, composite nut samples were collected from each site. Both leaf and nut samples were dried and ground prior to sending them to the DANR Analytical Laboratory located on the UC Davis campus to estimate their nutrient concentration (N, P, K, S, Ca, Mg, B, Zn, Fe, Mn, Cu).

Statistical procedures, so far, have consisted of stepwise regression and cross validation analysis, kriging interpolation technique, and mixing modeling analysis.

Results and Discussion

The effect of the presence of fruit on the leaf tissue values and changes through the season are shown in Figure 1. These results show a consistent and highly repeatable depletion of N, P, K, S, Zn, and Cu in fruiting spurs as crop develops and also that fruiting spurs can exhibit nutrient deficiencies even when non-fruiting leaves on the same tree may have “adequate” leaf concentrations. This observation, which needs confirmation, suggests that spurs behave as semi-autonomous units (behaving independently of each other and the tree as a whole) with the autonomy of the spur unit increasing as yield increases.

In addition, Figure 1 illustrates that nutrient concentrations and their variability depend on the nutrient sampled, sample type and sampling time. For the specific case of nitrogen, statistical analysis demonstrates that leaf nitrogen content can be well predicted with an early season (April) sampling (Table 1). The method developed to precisely predict nitrogen utilizes the analysis of tissue concentrations of 11 essential plant nutrients in F2 leaves collected in April. Results presented in **Table 1** contrast July N values predicted from April sampling against actual July N values at each of 4 sites over 3 years.

A second and more site specific model to predict July NF leaf nitrogen concentration only using nitrogen concentration in April is also being tested. This model relies on more assumptions than the first model and will be further validated this coming season using new almond orchards. The results so far are promising and we predict a high accuracy between predicted and observed values.

In addition, both models aim to account for two common situations that make the interpretation of foliar analysis difficult. The first situation is that samples collected do not always represent the true nutrient status of the orchard as a whole. The second situation is that orchard variability is not generally considered. Utilizing results based upon the three years of data analyses of moderately uniform and good producing orchards a new sampling protocol that allows growers to reliably estimate field mean nutrient status (**Table 2**) has been proposed. Both models assume that the variation recorded in this study is representative for California almond orchards. Thus, both models predict the percentage of trees that in July could be nitrogen deficient using a July nitrogen concentration of 2.2 as the July critical value (**Figure 2**). The number of samples suggested in Table 2 presumes that the sampled orchard has similar degree of variability as those orchards used in the development of the methodology. If the orchard of interest has well known zones of different soils and productivity then this sampling pattern should be applied independently to each zone.

In conclusion, results of this current project suggest that early season sampling is a viable methodology for predicting the occurrence of nutrient deficiency and that leaves of fruiting spurs may experience deficiencies even when leaves on non-fruiting spurs are apparently sufficient. This result implies that almond spurs behave in a semi-autonomous fashion and that targeted correction of spur deficiencies may be beneficial. While the sampling of orchards earlier in the season would be useful for management by providing important information on current orchard nutrient status and adequate time to correct deficiencies, it is essential that samples be collected in a statistically valid manner.

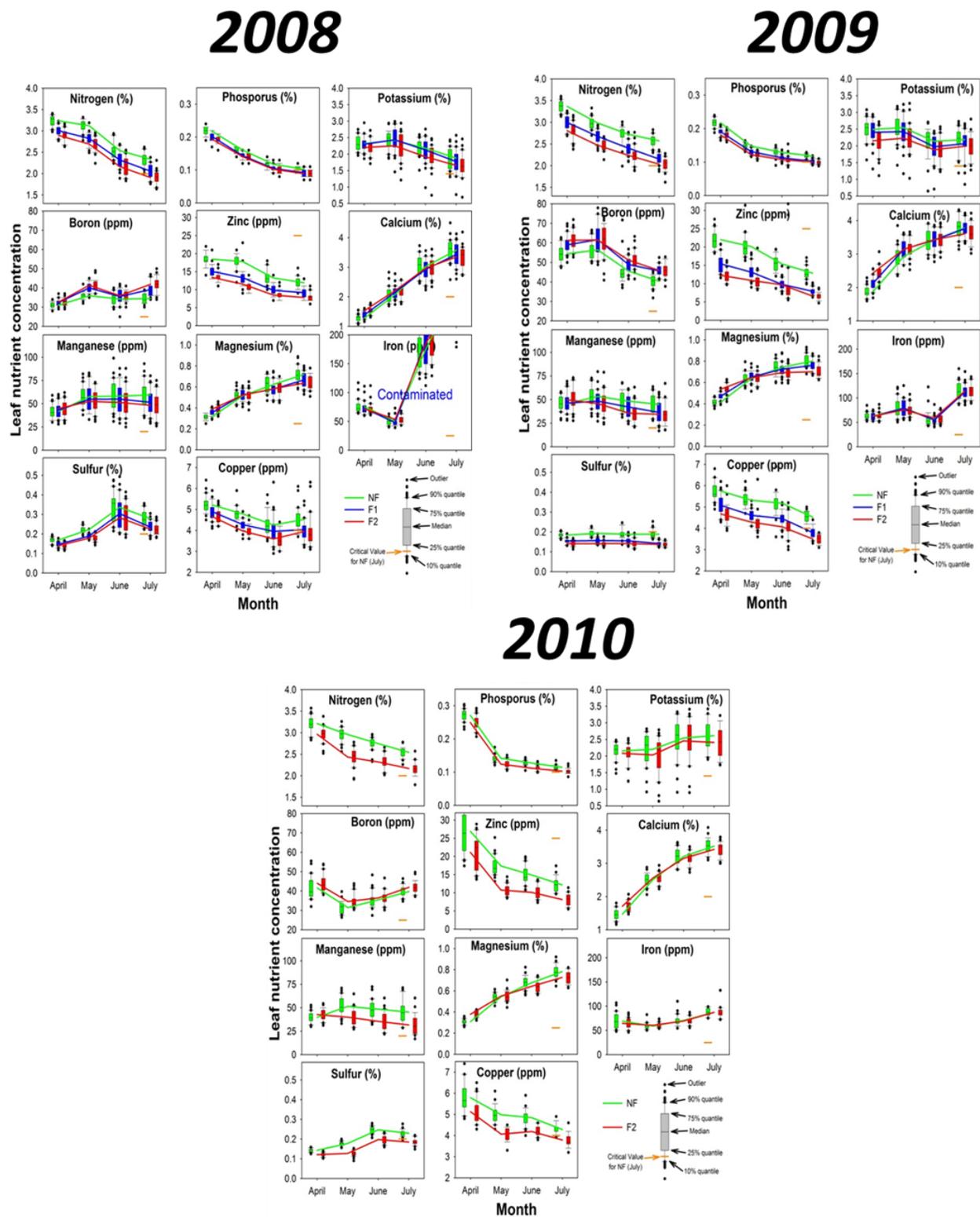


Figure 1. Nutrient behavior throughout 2008, 2009, and 2010 season in leaves from non-fruiting spurs (NF), spurs with 1 fruit (F1), and spurs with 2 fruits (F2). The graphs show data collected from the Arbuckle orchard.

| Site | Year | July Nitrogen Predicted | July Nitrogen Observed |
|----------|------|-------------------------|------------------------|
| Arbuckle | 8 | 2.4 | 2.3 |
| Belridge | 8 | 2.4 | 2.4 |
| Madera | 8 | 2.5 | 2.4 |
| Modesto | 8 | 2.4 | 2.4 |
| Arbuckle | 9 | 2.4 | 2.6 |
| Belridge | 9 | 2.4 | 2.4 |
| Madera | 9 | 2.6 | 2.4 |
| Modesto | 9 | 2.6 | 2.7 |
| Arbuckle | 10 | 2.4 | 2.5 |
| Belridge | 10 | 2.3 | 2.7 |
| Madera | 10 | 2.3 | 2.3 |
| Modesto | 10 | 2.4 | 2.5 |

Table 1. Site cross-validation of Model 1 results.

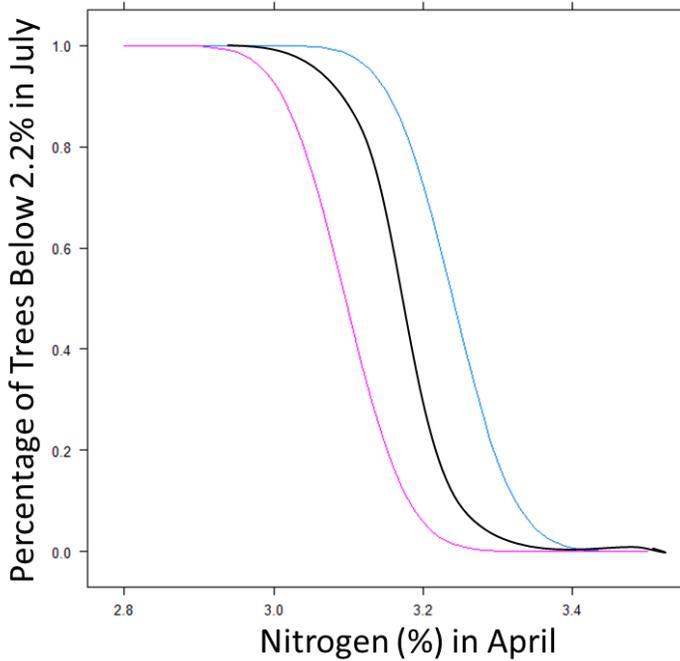


Figure 2. Model 2 output. Expected % of trees below 2.2% in July predicted by model 2. Black line = predicted. Blue Line = upper CI. Pink Line = Lower CI.

| Number of Acres | Trees needed at 95% Confident | Trees needed at 90% Confident |
|--|-------------------------------|-------------------------------|
| 2 | 25 | 18 |
| 5 | 27 | 19 |
| 10 | 28 | 19 |
| 50 | 28 | 20 |
| 100 | 28 | 20 |
| Note: 1 acre is assumed to be 100 trees | | |

Table 2. Number of trees needed in April to predict July-Nitrogen-Concentration.

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How to Improve Nitrogen Use Efficiency in Fruit and Nut Crops Without Government Regulation

R. Scott Johnson, Extension Specialist, UC Kearney Agricultural Center
9240 S. Riverbend Ave, Parlier, CA 93648
Phone (559) 646-6547, FAX (559) 646-6593, sjohnson@uckac.edu

No one appreciates government regulations, especially growers and their consultants. Even university researchers and extension personnel, as well as the regulators themselves, would prefer voluntary over mandatory programs. As a fruit industry, what can we do to encourage voluntary fertilization programs and stave off government intervention?

In the 30 years I have been working for the University of California, I have seen some progress in this area. We conducted a survey in the 1980s of fertilizer usage in stone fruit orchards. The average nitrogen application at that time was about 168 kgsN/ha (150 lbsN/acre). In recent years I have talked to many fruit growers who apply only half that amount or even less. Growers of other fruit, vine and nut crops claim they also are applying less fertilizer now than they were 30 years ago. The reasons they give for this reduction are many and include the following list:

1. Better yields
2. High cost of fertilizer
3. Reduced pruning costs
4. Improved fruit quality
5. Less pest and disease pressure
6. More efficient application methods
7. More confidence in leaf or petiole analysis
8. Repeated message from experts
9. Field demonstrations

Growers are unique and each has his own set of priorities and philosophy of farming. No two individuals respond to an approach or a piece of information in the same way. Thus, we must continue to develop this list so we can appeal to more and more growers. Here are a few examples to illustrate the point. First, one grower near Kearney had a tendency to over fertilize his stone fruit orchards and seldom attended our educational meetings where we talked about nitrogen use efficiency. When fertilizer prices shot up recently, he decided to cut back on his rates and contacted his farm advisor for advice. This then opened the door for discussion about other reasons for cutting back. He is now more careful about fertilizer rates because of the effect he sees on fruit quality. Second, many years ago we conducted extensive research on foliar urea as a means of efficiently supplying fruit trees with some nitrogen (Rosecrance et al., 1998a; 1998b; Johnson and Andris, 2001; Johnson et al., 2001). The practice was picked up by a few growers, but once Roger Duncan showed it decreased bacterial canker, it caught the attention of many more. Our work with nectarine nutrition involved many disciplines including entomologists, plant pathologists, postharvest physiologists and horticulturists (Daane et al., 1995). The many findings of this group provided multiple reasons for growers to cut back on nitrogen fertilization.

It should also be noted that different crops and different size operations might have very different reasons for cutting back on fertilization. For example, yields don't tend to be reduced by over fertilization in peach orchards. However, they can be reduced in grape vineyards and apple orchards and this is probably the main factor controlling fertilization rates in these crops. As another example, almond orchards are mostly irrigated with drip or low volume irrigation systems. This allows for fertigation, a more efficient method of fertilization, and is probably the main reason for reduced nitrogen applications in almond orchards (Lopus et al., 2010).

As we look to the future, what can we do to improve nitrogen use efficiency in fruit and nut orchards? First, it is important to continue applied research so that recommendations are based on good science. Research also helps growers develop greater confidence in the various programs proposed by university experts and other groups. Funding from commodity boards and FREP has been very helpful for this type of research. Second, we need to continue outreach programs and expand the approaches we use to educate growers. Classroom meetings, one-on-one consultations, field demonstrations, grower testimonials, field guides, newsletters, bulletins and websites should all be employed. Often it takes multiple contacts to convince someone to implement a new procedure. There are many well-known improvements in efficiency, such as fertigation, split applications, leaf sampling and better timing that need to be more universally adopted. Finally, we should encourage growers to be more proactive in this area. Regulators generally back off if the growers are making a concerted effort to develop programs on their own. Thus, anything they can do to document improvements in nitrogen use efficiency would be useful. These might include implementing the well-known improvements in efficiency mentioned above (fertigation, split applications etc), taking regular leaf samples and then using the information to guide fertilizer rates, sampling irrigation water for nitrates and using legumes or foliar urea to supplement soil fertilization. Any of these practices could be fairly simple and inexpensive to implement, but could go a long ways towards preventing mandatory programs.

We have made substantial progress in improving nitrogen use efficiency in fruit and nut crops. However, there is still much to do and many tools are already available to do it with. Even though there may be fewer research and extension people in the future, there are still many things growers can do to make improvements.

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Improving Nitrogen Use Efficiency in Intensive Vegetable Production

Richard Smith

Farm Advisor, University of California Cooperative Extension, Monterey County

1432 Abbott Street, Salinas, CA 93901

831-759-7357; rifsmith@ucdavis.edu

Introduction

The coastal vegetable production district has mild summer temperatures due to proximity to the ocean and is an ideal location for cool season vegetable production. Lettuce production in Monterey and Santa Barbara Counties is valued at \$1.337 billion dollars (Agricultural Commissioners reports, 2010) and supplies over 80% of the lettuce produced in the US from spring through fall (NASS 2010). Other vegetables produced in the coastal region include artichokes, broccoli, cabbage, cauliflower, celery, spinach and many others. These commodities are high value and have high production costs, as well strict quality standards. Intensive production practices used to produce these crops include double cropping and the use of robust quantities of irrigation water and fertilizers. These practices have helped growers produce high quality crops and yields. However, contamination of surface and ground waters with nitrate from vegetable production fields is under scrutiny by the Central Coast Regional Water Quality Control Board (CCRWQCB).

The draft Agricultural Order issued by the CCRWQCB increased the regulation of discharges of nitrate-nitrogen ($\text{NO}_3\text{-N}$) to surface and ground water. The new regulations require growers to implement a certified Irrigation and Nutrient Management Plan to document information on nitrogen applied to crops vs nitrogen taken up by the crop. This information would be used to calculate a nitrogen balance ratio and growers are given three years to demonstrate nitrogen balance ratios of 1.0 for annual rotations that are double cropped. In other words, if double cropped lettuce annually takes up 240 lbs of N/A (120 lbs N/A/crop), the annual amount allowed to grow two crops of lettuce in order to comply with the nitrogen balance ratio would be 240 lbs N/A/year.

In the past, it has been difficult for growers to economically justify reducing fertilizer rates because of the relatively low cost of fertilizer inputs in relation to the total production budget (e.g. <5%, Tourte and Smith 2010). However, the new regulatory environment, as well as recent spikes in the cost of fertilizer, are changing perspectives on fertilizer practices for leafy green vegetables on the central coast.

Improving Nitrogen Use Efficiency

Improving nitrogen use efficiency is essential to help the growers move towards compliance with the CCRWQCB Agricultural Order and reduce nitrate losses to ground and surface waters. There are several practices that can help growers comply with CCRWQCB regulations. Testing the soil to measure quantity of residual soil nitrate is critical to understanding how much supplemental fertilization is needed to achieve optimal crop yield (Breschini and Hartz 2002). In addition, irrigation management is critical to maintain nitrate in the root zone of the crop and reduce leaching losses (Cahn and Smith 2009). However, irrigation management is made difficult by the shallow rooting depth of many cool season vegetable crops (Figure 1). At the end of the growing season, a deep-rooted, over-wintered crop can scavenge residual soil nitrate from the soil profile and thereby reducing nitrate leaching. Cover crops are useful in this regard because they take up nitrate and incorporate it into the crop biomass, making it unavailable for leaching

by winter rains (Smith et al. 2011). Unfortunately, cover crops use is limited due to high land rents and vegetable planting schedules in the spring.

It is critical to understand the nitrogen uptake pattern vegetables to effectively plan nitrogen fertilizer applications. Total nitrogen taken up by cool season vegetables is shown in Table 1. Nitrogen uptake by vegetables follows a predictable pattern (Figure 2) and can provide a useful guide to adjusting the timing and rates of N applications. This is important because applying high rates of nitrogen fertilizer too early in the growth cycle can result in the leaching of nitrate before it can be utilized by the crop.

Enhanced nitrogen fertilizer such as controlled release fertilizers, urea and nitrification inhibitors, calcium cyanamid and others may be able to improve nitrogen use efficiency. Controlled release fertilizers come in many forms, but generally meter nitrogen to the soil solution by use of diffusion through a plastic coating on urea prills or urea polymers that must be broken down by microbes to release mineral nitrogen. Urease inhibitors temporarily inhibit the urease enzyme and can slow the conversion of applied fertilizer to nitrate. Nitrification inhibitors slow the conversion of ammonium to nitrate. In trials conducted in Salinas, Agrotain Plus (a combination of urease inhibitor and the nitrification inhibitor dicyandiamide (DCD)) gave improved yield at a moderate rate of nitrogen fertilizer (100 lbs N/A) over a treatment with the same amount of nitrogen but without Agrotain Plus (Figure 3). This was the first trial in which we successfully obtained a statistically significant improvement in yield with the use of a nitrification inhibitor at a moderate rate of nitrogen. More research is needed on all enhanced nitrogen fertilizer products to determine if they can consistently improve the nitrogen use efficiency of cool season vegetables.

A critical practice for reducing nitrate leaching losses is to reduce the quantity of residual nitrogen in the soil at the end of the growing season before the onset of winter rains. This can be achieved by using as much of the residual soil nitrate by the second vegetable crop. Careful testing of the soil nitrate levels with the soil nitrate quick test can guide fertilizer applications in the second crop and reduce nitrogen applications; this practice can reduce the levels of nitrate in the soil at the end of the growing season (Table 2).

Winter cover crops can take up residual soil nitrate and reduce the risk of nitrate leaching with winter rains. Nitrate taken up by the cover crop is sequestered in the crop biomass and not subject to leaching winter rains (Figure 4).

In summary, there are opportunities for growers to effectively improve nitrogen use efficiency in cool season vegetable production. The challenge is for growers to reconcile the costs and risks of practices that improve nitrogen use efficiency with production practices that safeguard yield and quality of their crops.

Table 1. Nutrient content of Salinas Valley crops at harvest (lbs/acre).

| Crop | Nitrogen | Phosphorus | Potassium |
|----------------|-----------------------|------------|-----------|
| Lettuce | 90 – 140 ¹ | 11 – 15 | 150 – 180 |
| Broccoli | 180 – 220 | 25 – 30 | 160 – 240 |
| Cauliflower | 180 – 220 | 25 – 30 | 160 – 240 |
| Celery | 180 – 240 | 40 – 45 | 350 – 450 |
| Spinach - clip | 80 – 120 | 2-4 | 25-55 |

1 – higher nitrogen uptake occurs on 5-6 seedlines on 80 inch beds

Table 2. Nitrogen balance of fertilizer applied, removed and remaining in lettuce fields

| Treatment | Fertilizer N applied lbs N/A | Crop N uptake lbs N/A | N removed in harvested product lbs N/A | Nitrogen balance lbs N/A |
|--|---------------------------------|--------------------------|--|--------------------------------|
| Standard | 248 | 134 | 67 | +181 |
| Use of quick test to guide fertilizer application | 110 | 142 | 71 | +39 |

Figure 1. Number of spinach roots at six depths (inches) in the soil (clipped spinach approximately 35 days old)

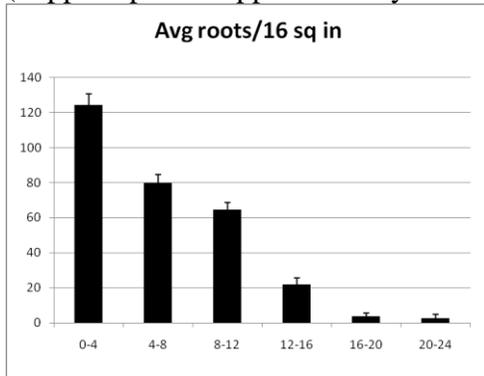


Figure 2. Nitrogen uptake (lbs/A) by lettuce (left) and spinach (right) over the growing season (X axis is days after planting).

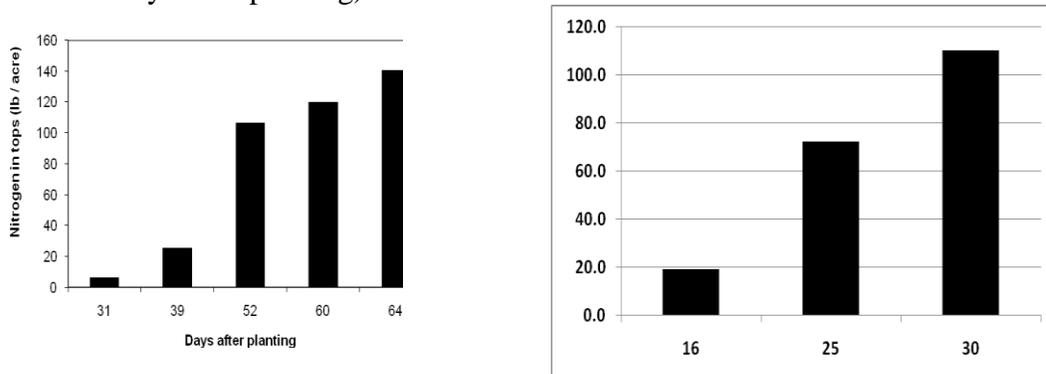


Figure 3. Yield of romaine lettuce at three fertilizer rates and with and without nitrification inhibitors

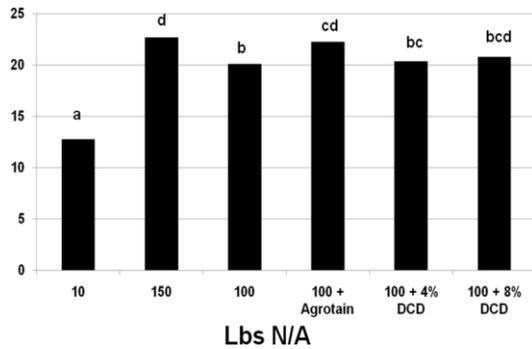
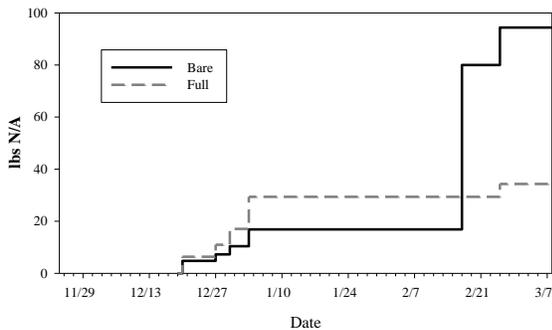


Figure 4. Nitrate in the soil in the cover crop treatment and bare fallow during the winter 2010-11



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Insights from the California Nitrogen Assessment

Sonja Brodt, Daniel Liptzin, Todd Rosenstock, Karen Thomas, Colin Bishop, Aubrey White,
Thomas P. Tomich
Agricultural Sustainability Institute, UC Davis

Introduction

Nitrogen (N) plays a critical role in food production in California and around the world, but the tradeoffs of nitrogen use involve negative consequences for the environment and human health. Despite increasing awareness of the importance of these tradeoffs, a lack of cohesive knowledge that gives a big-picture view of California's nitrogen system still hampers effective decision-making from the policy level down to the individual field level. The California Nitrogen Assessment (CNA) was designed to fill this void.

The assessment establishes a baseline of credible knowledge about nitrogen, which includes comprehensive accounting of nitrogen flows, agricultural practices, and the policies that shape these practices. Furthermore, it examines the environmental and human well-being tradeoffs involving nitrogen and assesses the quality of information and knowledge about these issues. The results lay the groundwork for informed discussion, debate, and decision making on nitrogen management and policy in California.

Methods

The CNA follows the established protocol for integrated ecosystem assessments (Ash et al. 2010), as exemplified by the global-scale Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) and the Intergovernmental Panel on Climate Change (IPCC 2007). When conducting an assessment, the *process* is as important as the results and outputs produced. Following the MA protocol, the California Nitrogen Assessment developed a process to observe three fundamental criteria: credibility, usefulness, and legitimacy. Key to achieving these core values was a strategic stakeholder engagement process. Engaging stakeholders early in the assessment not only helps to shape the assessment's approach and ensure that outputs meet the needs of key end users, but also ensures that the results are seen as legitimate by as many affected stakeholder groups as possible. We engaged stakeholders through multiple avenues, including a Stakeholder Advisory Committee (SAC) comprised of 28 representatives from government agencies, environmental and health advocacy non-profit organizations, and producers and agricultural commodity groups. The SAC was intentionally weighted on the side of producers and users due to this group's large role in nitrogen use and management. The SAC commented on early drafts of key assessment documents and acted as a liaison between this information and the members' constituencies. The committee also participated in a facilitated group scenario-building exercise envisioning the future of nitrogen in California agriculture. This exercise led to the development of four distinct scenarios of how nitrogen-relevant technologies and policies might unfold in the next 20 years and how these would affect nitrogen use and impacts.

In addition to interacting with the SAC, the assessment team also visited groups of growers, farm advisors, government agencies, and environmental and health organizations around California. Key engagement activities included multi-stakeholder workshops, small-group consultations

with growers, and individual contact via phone and email. Altogether, the team interacted directly with more than 200 individuals across a wide range of organizations. These stakeholders collectively generated over 100 questions about nitrogen use and its impacts in California that our team then synthesized into five overarching research areas, comprising the science of nitrogen flows, on-farm practices, public policy, public health, and communications (Figure 1).

To ensure scientific credibility, the assessment team, which includes scientists with agronomic, environmental, and social science backgrounds, engaged a broad range of scientists at UC Davis and other institutions, through one-on-one contact, focus group meetings, and co-authoring relationships. A 9-member, multidisciplinary Technical Advisory Committee also provided guidance on the team's approach.

Preliminary Results

The assessment compiles and summarizes data along a logical sequence of human-environment relationships, as summarized in a conceptual framework (Figure 2). We first identified important underlying drivers of nitrogen use decisions, including factors such as growth in global demand for California commodities, prices of fuel and fertilizers, demand for transportation, and others. These underlying factors, in turn, influence direct drivers of nitrogen use, such as growth in acreage of high nitrogen-demanding crops, concentration of animals in feedlot dairies, fossil fuel combustion in vehicles, and others. These direct decisions, in turn, affect the statewide mass balance of nitrogen - the quantification of how much enters the state through new sources, how much of which nitrogen-containing compounds are transformed from one form to another, and ultimately, how much of these varied compounds enter the environment. From there, we investigate the impacts on environmental health and human well-being of these varied forms of nitrogen leakage, including nitrates in surface and groundwater, NO_x in the air, N_2O in the atmosphere, and others. Finally, we examine the state of the science around the most promising technical and policy solutions to minimizing nitrogen leakage.

Preliminary results for the mass balance show that cropland is by far the largest source of nitrogen outflows into the environment, with livestock operations the second largest. Other sources such as urban areas, sewage, and natural lands account for substantially smaller proportions of outflows on a statewide basis. Fertilizer accounts for one-third of statewide total new nitrogen inputs annually, with NO_x emissions from fossil fuel burning accounting for the second largest amount of new nitrogen inputs - almost one-quarter. While combustion-related emissions are declining due to implementation of engineering controls, similar trends are not quite as evident in agriculture. However, field scale studies on certain crops suggest the potential to achieve higher nitrogen use efficiencies than current statewide averages, using already existing technologies.

Conclusions

Due to the mobility of nitrogen and its occurrence in multiple forms, the most efficacious strategy to addressing nitrogen leakage in agriculture will likely be one that integrates across multiple biogeochemical processes, spatiotemporal scales, and nitrogen sources. Such integration will require careful consideration of the technical potential of different farming practices to limit total nitrogen inputs and increase nitrogen use efficiency, while also accounting for the potential tradeoffs that can occur when practices that limit one form of nitrogen pollution increase another

form. Technology implementation will need to be coupled with smart policies that address such tradeoffs while also recognizing the complex, multi-objective context in which farm managers make on-the-ground decisions to maintain the viability of their operations.

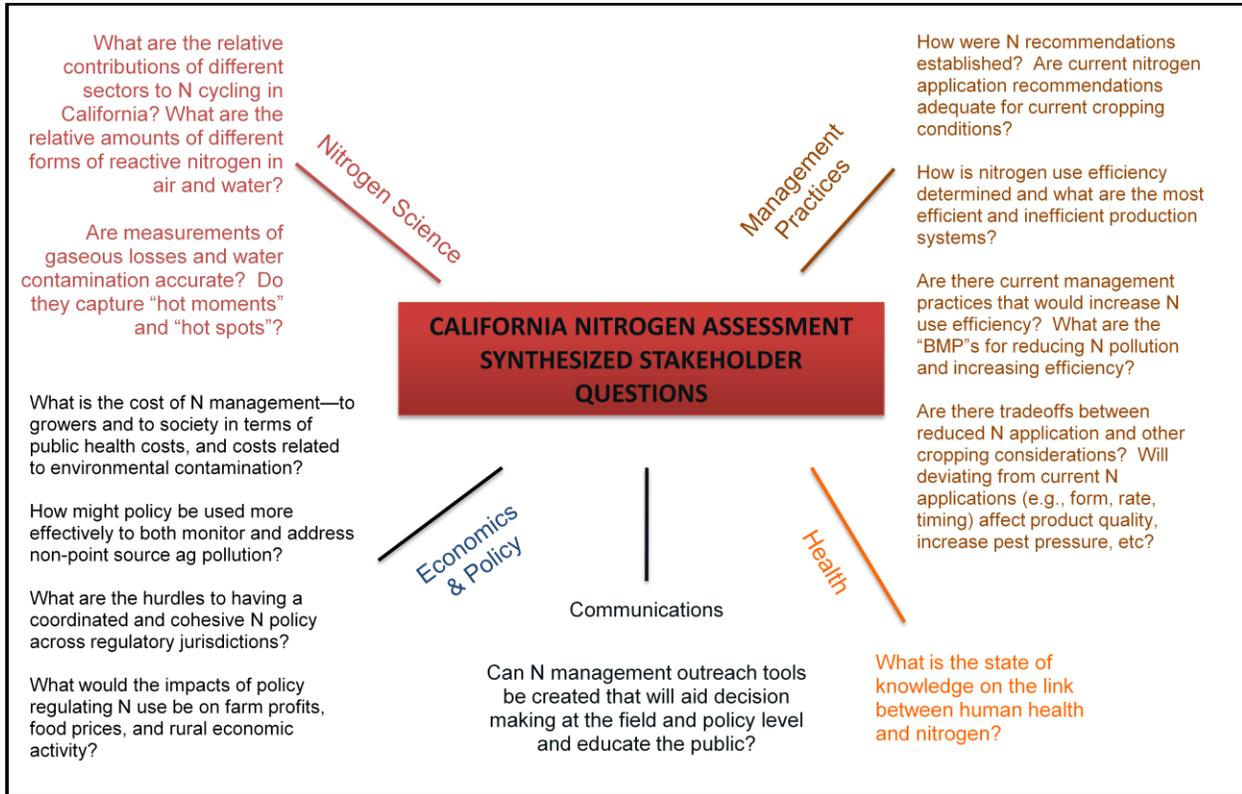


Figure 1. Major categories of stakeholder-generated questions about nitrogen

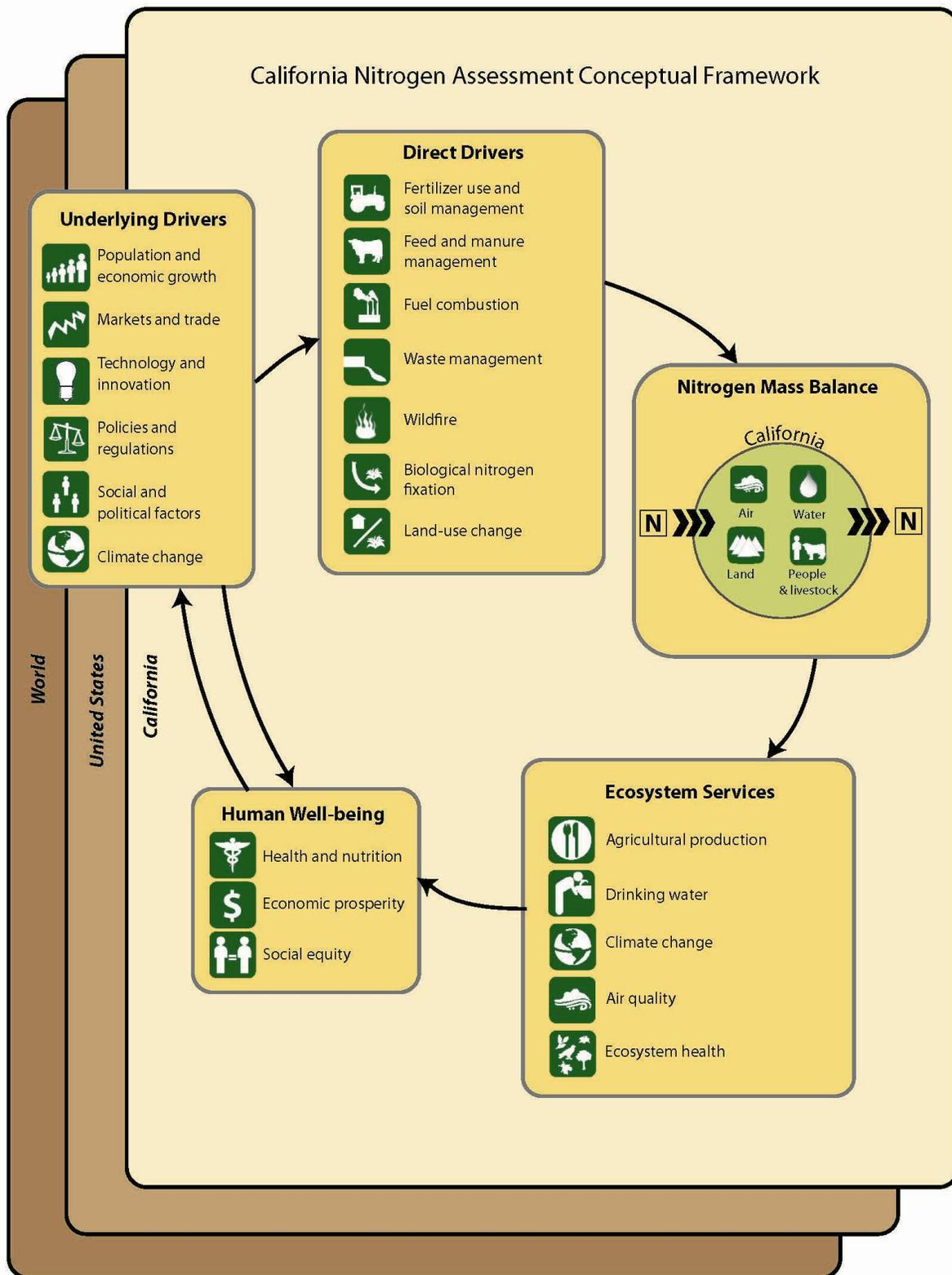


Figure 2. California Nitrogen Assessment Conceptual Framework

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Soil & Plant Nutrient Analyses – Perspective from the Field

Keith M. Backman _ Consultant Manager -Dellavalle Laboratory, Inc.
Certified Crop Advisor _ Calif. State Board and Int'l Exam Committee
422 N. Douty St., Hanford, CA 93230 559 647-5330
kbackman@dellavallelab.com

Farming to create a premium crop is not done by just collecting accurate leaf, soil, and water samples. It is done by having a well thought out fertility plan for your crop. This plan needs to be in place at the beginning of the season and should include the source, rate, time & place of each anticipated nutrient application.

THEN: This information is adapted and updated during the season using information from leaf, soil, and water analysis information. Over reacting, guessing, changing due to coffee shop gossip, recommendations by individuals who are not familiar with your property, and/or adding something that works somewhere else, will warp your plan and the crop.

Too often farmers and consultants consider a nutrient management plan something that records what has been done. A nutrient “history” is not a nutrient “plan!” As consultants we need to provide scientific assistance to fine tune the farm’s plan. Providing information without proper integration into that plan just creates a new problem.

Assembling a Nutrient Plan

Components should include the anticipated:

- Soil Carryover Nitrogen
- Preplant Nitrogen (source, rate, time, place)
- Compost/Manure Nitrogen Contribution
- Irrigation Water Nitrogen (estimate)
- In-season Nitrogen (source, rate time, place)
- Foliar Nitrogen
- Other Nitrogen
- Other nutrient applications

Obviously many of these figures are educated guesses and dependant on many factors. (Not that different than a farmer putting together an anticipated cash flow budget for his banker.) As the season progresses items such as weather, changes in water sources, actual application changes, crop development changes, etc., etc., will require adaptation as the crop matures. Lab samples will be used to reduce input where excess nutrients are detected and apply supplemental nutrients when a short supply is first detected.

The crop advisor will be using agricultural science to assist the farmer to create an excellent crop with an efficient use of resources.

Estimating Plant-available K in K-fixing Soils

Gordon L. Rees, G. Stuart Pettygrove, Randal J. Southard
Department of Land, Air and Water Resources, University of California, Davis
One Shields Ave.
Davis, CA 95616

Introduction

Potassium is an essential element in plant nutrition, and a sufficient supply of K is required to maximize crop yield. Understanding crop K requirements and being able to accurately measure the amount of K in soil that is available to plants is necessary to avoid K deficiencies while minimizing wasteful applications of fertilizer K. K deficiencies have had a large negative effect on cotton production in California, with yield reductions seen in about one fifth of the cotton acreage in the San Joaquin Valley (Cassman et al., 1990). Careful K management is also especially important in vineyards, where excess K can harm fruit quality for wine production (Mpelosoka et al., 2003).

Soil K is found in different forms that determine its availability to plants. K is often found in high concentration in soils as a constituent of soil minerals including feldspars and micas, but this mineral K is structurally bound making it unavailable to plants. Mineral weathering can result in the release of K^+ ions to the soil solution where it is available for plant uptake, or exchange with other cations on soil cation exchange sites. K can also be removed from solution through K fixation, the relatively strong adsorption of K by soil minerals in a non-exchangeable form. Plants can still access some of this fixed K, but it is less readily available than solution and exchangeable K.

The extent to which K is fixed in a soil is determined by the mineral make-up of that soil. Vermiculite (a phyllosilicate mineral formed from the weathering of micas) has been shown to be primarily responsible for the fixation of K. Vermiculite fixes K by trapping it between the layers of the mineral (Sparks and Huang, 1985). Vermiculite is commonly found in the silt and fine sand-sized fractions of weakly- to moderately-weathered soils formed from granitic parent materials. These soils with a high potential for K fixation are commonly found along the east side of the San Joaquin Valley and southern Sacramento Valley of California (Murashkina et al., 2007a,b). For our current research, we have selected soils sampled from six sites (at multiple depths) with a range of K fixation potential – four from vineyards in the Lodi winegrape district, and two from cotton fields in Fresno County.

Measuring Soil Potassium

Measuring levels of soil potassium in a meaningful way can be challenging, especially in soils with high K fixation potential. The standard laboratory method for measuring soil K is extraction with neutral 1N ammonium acetate (NH_4OAc) (Soil Survey Staff, 2004). This method gives a value for soluble plus exchangeable potassium. It fails to extract fixed (non-exchangeable) K, some of which is plant available. Other methods have been developed to try to give a more accurate measurement of total plant-available K, including extraction with sodium tetraphenylboron ($NaTPB$). This method, developed by Scott et al. (1960) and modified by Cox

et al. (1996, 1999), has been shown to more closely correlate with K uptake by plants. For the soils in this study, the NaTPB method extracted between 1.8 and 7.8 times as much K as the NH₄OAc method.

In addition to measuring the available K in the soil, in K-fixing soils it is important to know the potential of the soil to fix additional K. A one-week K fixation potential test was developed by Cassman et al. (1990) and modified to a simplified one-hour test by Murashkina et al. (2007a). Though this method gives a value of K fixation potential (Kfix) in ppm, it should not be considered a measure of the absolute amount of K a soil can fix, but instead a value relative to the amount of K added in the procedure and relative to the values of other soil samples.

By using the combination of these three methods - NH₄OAc, NaTPB, and Kfix – we have been able to better understand the dynamics of K added to soils as it moves between the various soil pools measured by these tests.

Key Findings

In order to analyze the effect of several factors on the fate of potassium added to the soil, we began by adding KCl in solution to our air-dried soil samples at a concentration of K⁺ equal to the initial Kfix value determined for each sample. Soils with higher K fixation potential received higher levels of K than soils with lower Kfix values. Samples were then incubated moist at room temperature (about 21° C) for 1, 2, 4, 8, or 16 days. After incubation, moist soil samples were analyzed by the NH₄OAc and Kfix methods discussed above (the NaTPB method was not adequate for analyzing moist samples). Subsamples were also removed and allowed to air-dry, after which they were analyzed using the NH₄OAc and Kfix methods, as well as the NaTPB method. Additionally, samples from one soil were subjected to four cycles of wetting and air drying after the initial application of K and analyzed after each drying cycle. A summary of averaged results is illustrated in figure 1.

Even after adding K equal to the Kfix values for these soils, they all continued to fix additional K, though at levels lower than for the untreated soils. In other words, the added K did not fully satiate the K fixation potential of these soils.

K extracted by both NH₄OAc (NH₄OAc-K) and NaTPB (TPB-K) increased after K addition, but by some amount less than the K that had been added in solution. This indicates that these soils fixed a portion of the added K, and some of this fixed K was removed from the pool of plant-available K as measured by NaTPB extraction.

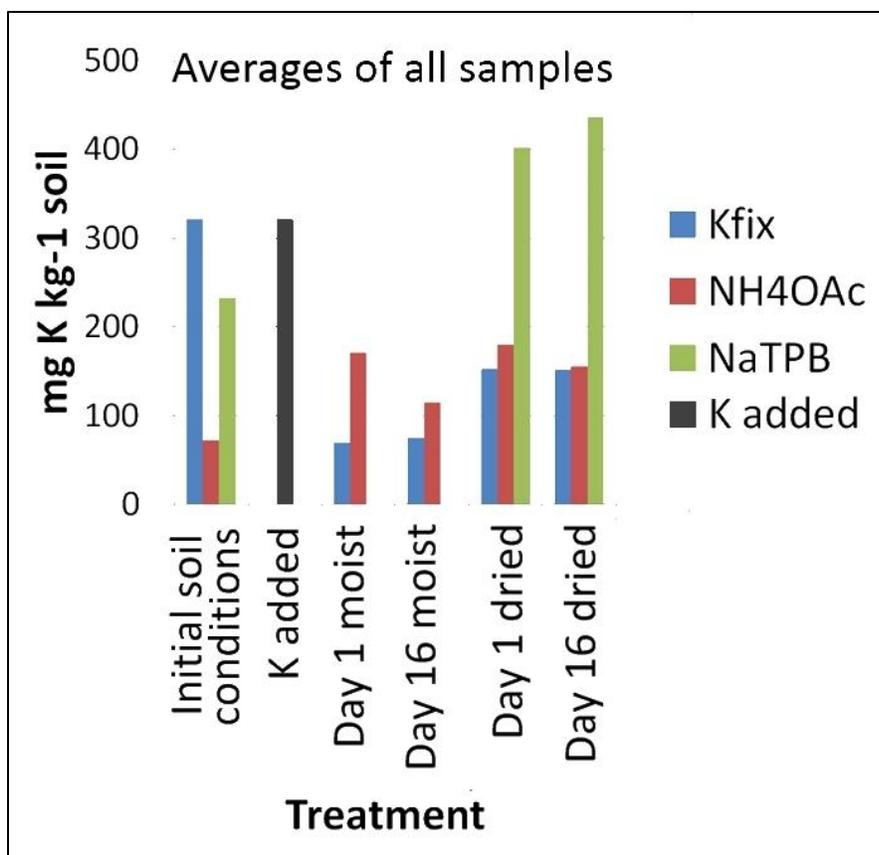


Figure 1. Averaged values for each analysis for several treatments for all samples.

Effect of incubation time – Kfix values were independent of the duration of incubation. Changes to the fixation potential of these soils after the addition of K appeared to all take place in the first 24 hours. NH₄OAc-K and TPB-K values behaved less consistently. There was an apparent slight downward trend in NH₄OAc-K with time for some, but not all samples, and an apparent slight upward trend in TPB-K for some, but not all samples.

Effect of air drying – For all soil samples analyzed, Kfix values for moist samples were lower than for their dried counterparts. This indicates that air drying results in an increase in the potential for soils to fix potassium. Under field conditions, drying to this extent is not realistic, but this result may provide clues to the mechanisms involved in K fixation. Air drying did not have a consistent effect on NH₄OAc-K.

Effect of wetting and drying cycles – Additional cycles of wetting and air drying had no discernable effect on the Kfix, NH₄OAc-K, or TPB-K values. What changes took place upon drying were not enhanced by repeating the wetting and drying process.

An additional experiment was run to determine the results of adding K equal to the CEC of the soil samples (a symmetry amount). This provided several times more K than the Kfix amount, and saturated the soil samples with K. By running the Kfix procedure on these samples, and comparing the excess K released to the amount of K added, we were able to determine an approximate maximum absolute value for the K fixation potential of the soils. Results from the

NH₄OAc and NaTPB methods confirmed previous conclusions: the NaTPB method extracted more K than the NH₄OAc method, and recovered some, but not all, of the added K that had been fixed.

Summary

Additions of K to K-fixing soils results in a new distribution of K across the various pools of soil K. Some of the added K remains exchangeable, some becomes non-exchangeable, but still plant available, and some is fixed in a non-plant-available form. This information, along with our results from an expanded exploration of these effects, will be useful in understanding the fate of fertilizer K applied to K-fixing soils, and in developing recommendations for overcoming the negative impacts of K fixation and K deficiency on crop yields.

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How Do Regulations Become Reality?

David Ceppos
Center for Collaborative Policy, CSU, Sacramento
815 S. Street, 1st Floor
Sacramento, CA 95811
(916)-445-2079

NOTES & QUESTIONS:

Key Agricultural Labor Regulations

Manuel Cunha, Jr., President
Nisei Farmers League
mcuna@niseifarmersleague.com
1775 N. Fine
Fresno, CA 93727
(559)-251-8468

NOTES & QUESTIONS:

Status of Air Quality Regulations for Agriculture

Roger Isom, Executive Vice President
California Cotton Ginners and Growers Association
1785 N. Fine Ave
Fresno, CA 93727
Phone: (559) 252-0684
roger@ccgga.org

NOTES & QUESTIONS:

Impact of air and water regulations or requirements on dairy management

Deanne Meyer, Livestock Waste Management Specialist, Department of Animal Science,
UC Davis, One Shields Avenue, Davis, CA 95616
dmeyer@ucdavis.edu

Introduction

California has an abundant agricultural bounty providing much needed economic input to many rural communities. In 2008, the sale of milk and cream accounted for \$6.9 billion of sales of the state's \$29.6 billion agricultural income. Additionally, dairy contributed to sale of cattle and calves (a \$1.8 billion dollar income) with an overall contribution of more than 25% of the state's agricultural income.

Most dairies are highly regulated. Dairy operations must meet stringent sanitation compliance and enforcement requirements stipulated by requirements of the Interstate Milk Shippers and enforced by the Food and Drug Administration and local regulatory inspection (either California Department of Food and Agriculture or County Inspector). Labor regulations are enforced by Cal OSHA (Occupational Safety and Health).

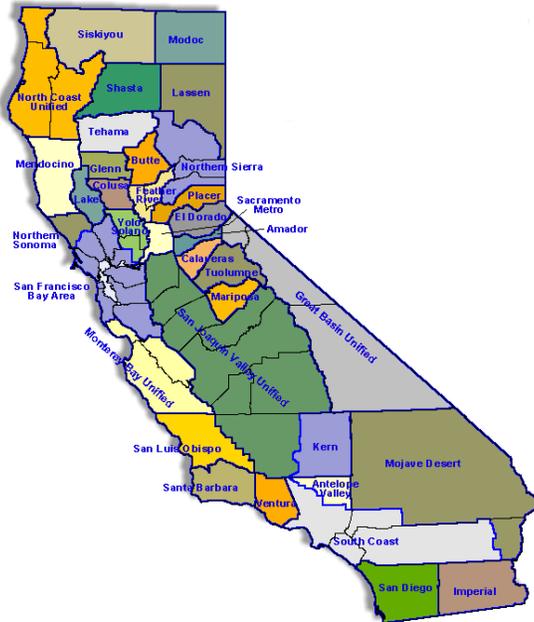
Most of the dairy cows are located in the San Joaquin Valley with smaller milksheds existing in Chino/San Bernardino, San Jacinto, Imperial, San Diego, the Sacramento Valley, Sonoma, Marin, Humboldt, and Del Norte Counties. The owners and operators of these facilities face ever changing environmental regulations that address Federal, State, Regional, and County requirements---depending on geographic area.

Air Requirements

The Clean Air Act (enforced by US EPA) serves as the Federal Act addressing National Ambient Air Quality Standards for criteria pollutants. Parts of this Act of interest to dairy operators are standards for atmospheric concentrations of particulate matter (dust) and ozone. Ozone formation can occur in the presence of NO_x and Volatile Organic Compounds (VOC). Districts out of attainment for PM or ozone have implemented plans to reduce emissions to below threshold concentrations. Mitigation plans are designed and implemented by numerous industries contributing to these emissions. Dairy is one industry impacted by non-attainment of Clean Air Act criteria pollutant concentrations.

There are 35 Air Districts in California. The San Joaquin and South Coast Districts both have permits and annual reporting requirements for dairy operators. The primary focus herein will be on the San Joaquin Air District.

California Air Districts



Rule 4550 was implemented and conservation management plans based on implementation of control techniques to control dust emissions were developed by many agricultural managers and submitted by December 31, 2004. Dairies (both the production facility and the crop growing area) were impacted by this Rule. In 2006, large dairies were also permitted through Rule 4570 and operators were obligated to develop and implement VOC reduction measures. The District air quality was very poor. When the District was designated as Extreme nonattainment for ozone it was required to further reduce emissions of VOC (ozone precursors). Rule 4570 was amended and Phase II mitigation plan was developed for previously permitted facilities as well as smaller facilities (>175 milk cows). Even for facilities with < 175 milk cows, a District Permit to Operate is required if emissions > 5 tons per year of VOC or NO_x although the facility would be exempt from Rule 4570. Medium sized facilities (between 176 and 500 milk cows) with emissions > 5 tons per year of VOC or NO_x require a District Permit and are exempt from Rule 4570 requirements. Larger facilities (>499 milk cows) must obtain the District permit and either medium or large Confined Animal Facility 4570 requirements apply. A facility can determine if it exceeds the 5 tons/year by completing the calculator at http://www.valleyair.org/General_Info/AGLoader.htm . Click on the “Do I Need a Permit” tab and follow the link to the worksheet.

Of greatest importance for all facilities with a Permit to Operate is that any management practice or infrastructure change on farm that will result in an increase in emissions in ANY permit unit (not a net increase over the farm) beyond 2 lbs a day requires the operator submit an Authority to Construct (ATC) application to the District for review PRIOR TO any facility modifications. Infrastructure changes as simple as remodeling of the milk parlor requires an ATC review (a change in throughput of animals changes the

amount of time animals are in the parlor versus housing area). Installation of shade structures requires submission of an ATC. When in doubt, an ATC should be submitted and approved prior to project work. Failure to correctly complete the regulatory requirements prior to modification can and usually will result in a penalty.

One of the new areas of VOC mitigations on dairies is Phase II Mitigation Measures for feed management. Feed management is front and center in this process. There are four required feed mitigations each operator must implement: Feed according to National Research Council (NRC) guidelines; push feed so that it is within three (3) feet of feedlane fence within two hours of putting out the feed or use a feed trough or other feeding structure designed to maintain feed within reach of the cows; begin feeding total mixed rations within two (2) hours of grinding and mixing rations; store grain in a weatherproof storage structure. The other feed category required the operator to select 1 of 3 options: Feed steam-flaked, dry rolled, cracked or ground corn or other ground cereal grains; remove uneaten wet feed from feed bunks within twenty-four (24) hours after the end of a rain event; for total mixed rations that contain at least 30% by weight of silage, feed animals total mixed rations that contain at least 45% moisture.

Management of silage piles provides numerous options for operations to reduce VOC emissions. Operators selected from one of two options: utilize a sealed silage storage system (e.g., Ag-Bag) or silage Pile Management. If the latter is selected there are required practices as well as optional practices. The required practices include covering the surface of silage piles, except for the area where feed is being removed from the pile, with: a plastic tarp ≥ 5 mils thick (0.005 inches), or multiple plastic tarps with a cumulative thickness of ≥ 5 mils (0.005 inches), and an oxygen barrier film covered with a UV resistant material within 72 hours of last delivery of material to the pile. Additionally, operators must select and implement one of the following: build silage piles such that the average bulk density of silage piles is at least 44 lb/cu ft for corn silage and 40 lb/cu ft for other silage types; or when creating a silage pile, adjust filling parameters to assure a calculated average bulk density of at least 44 lb/cu ft for corn silage and at least 40 lb/cu ft for other silage types, using a spreadsheet approved by the District; or incorporate the following practices when creating silage piles: harvest silage crop at $\geq 65\%$ moisture for corn; and $\geq 60\%$ moisture for alfalfa/grass and other silage crops; and manage silage material delivery such that no more than six (6) inches of materials are un-compacted on top of the pile; or incorporate the following parameters for Theoretical Length of Chop (TLC) and roller opening, as applicable, for the crop being harvested. Additionally, the operator must select and implement two of three measures: manage exposed silage surface (one silage pile = uncovered face has a total exposed surface area of less than 2,150 sq. ft; multiple silage piles = total exposed surface area of all piles is $< 4,300$ sq. ft.), Maintain silage working face (Use a shaver/facer to remove silage from the silage pile, or maintain a smooth vertical surface on the working face of the silage pile, or use Silage Additives (inoculate silage with homolactic acid bacteria; apply propionic acid, benzoic acid, sorbic acid, sodium benzoate, or potassium sorbate to reduce yeast counts when forming silage pile; or apply other additives at specified rates to reduce alcohol concentrations in silage and/or VOC emissions from silage must be approved by the District and EPA).

Additional rules include District Rule 4702 (Internal Combustion Engines—Phase 2), Rule 4621 and 4622 (Gasoline transfer into stationary storage containers and gasoline transfer into motor vehicle fuel tanks), Rule 4307 (boilers, steam generators, and process heaters), 4662 (organic solvent degreasing operations), and 2201 (new and modified stationary source review). Additionally, construction of a new dairy or expansion of an existing dairy is subject to CEQA analysis (California Environmental Quality Act).

Green house gases (GHG) are addressed by the California Air Resources Board as a result of AB32. According to CARB, three potentially readily adaptable GHG reduction activities can occur on dairies: anaerobic digesters, reduced energy use, improved irrigation efficiency resulting in reduced GHG emissions. From a GHG balance sheet anaerobic digesters are beneficial—however, it’s possible the net impact is viewed as negative if criteria pollutants are generated. A recent article written by staff at the District provides insight into permitting associated with anaerobic digesters on dairies.

Water Requirements

The Clean Water Act began as two sides of paper in 1848. It has been modified numerous times since. Although Federal EPA maintains the right and authority to conduct inspections within California, it is the responsibility of each of nine Regional Water Quality Control Boards to implement Porter Cologne and issue Conditional Waiver of Waste Discharge Requirements, Waste Discharge Requirements, or National Pollution Discharge Elimination System Permits to animal operations.



Southern California dairies have been covered under formal requirements for more than a decade. Operators in the San Francisco Bay region and the Central Valley have a formal regulatory process. The North Coast Regional Board should have adopted (Jan, 2012) a formal process for dairies.

Porter Cologne has requirements to protect beneficial uses of water---both surface and ground waters. As such, expectations by California Regional Water Quality Control Boards (Regional Board) are different in scope from other states in order to be protective of groundwater in addition to surface waters. Operators of facilities covered through General Waste Discharge Requirements are obligated to submit a Report of Waste Discharge (ROWD) to their Regional Board if they plan to have a material change in volume, location, or character of the waste stream(s). A few of the management considerations which would trigger submission of a ROWD to the Regional Board include changes in animal numbers, conversion of corral system to freestalls, modifications of land available for manure application.

Salt and nitrogen management are key to water quality protection. The Monitoring and Reporting Program (MRP) was developed to meet the needs of determining compliance with Nutrient Management and Waste Management Plan requirements. The General Order for Existing Milk Cow Dairies in the Central Valley has been in place nearly 5 years. The staged implementation plan should be in place with facility operators now managing facilities as identified during the early assessment phases. Modifications to the MRP or other components of the Order will occur over time.

The North Coast Regional Water Quality Control Board has established a three tier process for regulating dairies. The timeline and requirements (recommended versus mandated) for Waste and Nutrient Management Plans vary depending on the process selected. The Conditional Waiver of Waste Discharge requires submission of a Notice of Intent, followed by completion of the required Water Quality Plan (WQP). Both the Nutrient and Waste Management Plans are recommended. The General Waste Discharge Requirements and the NPDES permit have mandated times for compliance with the NMP.

Getting information in a timely fashion

The Partners in the California Dairy Quality Assurance Program (CDQAP) are committed to delivering technically correct information in a timely fashion as regulations change and understanding of implementation requirements is improved. Previous educational materials developed for compliance assistance are available at the CDQAP website (<http://www.cdqa.org/binder.asp>).

Summary

For dairies located in the San Joaquin Valley, any change in management which alters animal movement, manure deposition, or manure handling potentially needs prior approval from the Air District, the Regional Board, and potentially the County. Everyone working with dairy operators needs to be considerate of these regulatory obligations.

Helpful information:

http://www.waterboards.ca.gov/centralvalley/water_issues/dairies/index.shtml

http://www.waterboards.ca.gov/northcoast/water_issues/programs/dairies/

http://www.valleyair.org/General_Info/AGLoader.htm

<http://www.cdqa.org/>

Local Climate Action Plans: How Input from Agricultural Stakeholders Adds Value to Mitigation and Adaptation Efforts

Ryan Haden, Postdoctoral Associate
Department of Land, Air and Water Resources
University of California Davis
Davis, CA 95616
(530) 754-9637, vrhaden@ucdavis.edu

Louise Jackson, Professor and Extension Specialist
Department of Land, Air and Water Resources
University of California Davis
Davis, CA 95616
(530) 754-9116, lejackson@ucdavis.edu

Introduction

Agriculture is vital to the economy of California's Central Valley. California leads the nation in the production of fruits, nuts, vegetables and dairy products. The state is also at the forefront of legislation to protect air and water quality and most recently, in policies to mitigate climate change. Concerted efforts to plan for and adapt to higher temperatures, less snowpack, and potential drought are also being initiated. As California farmers balance these objectives, they also face numerous uncertainties. Will climate change dramatically influence water availability or alter which crops can be profitably grown? How will new government policies influence their day-to-day operations? How can they protect agricultural lands from rapid urbanization? How will changes in global commodity markets affect their bottom line? Anticipating and adapting to these uncertainties will be crucial for the future viability of California agriculture (Figure 1).

Yolo County as a Case Study for Climate Change Mitigation and Adaptation

In this article we discuss how one rural community in California's Central Valley, Yolo County, is already preparing for the future. We focus on Yolo County for several reasons. First, as a county it has many attributes typical of the Central Valley: small towns and cities with a changing mixture of urban, suburban, and farming-based livelihoods. Its agricultural landscape includes a mix of irrigated row crops and orchards grown on alluvial plains; and grazed rangelands in the uplands along the eastern edge of California's Coastal Range. The second reason is that Yolo is among the first rural counties in California to specifically address climate change mitigation and adaptation in their recently passed "climate action plan". Not surprisingly, concern about the impact of both climate change as well as the new state and local policies have brought a diverse range of stakeholders into the discussion. We also focus on Yolo County because of the relative wealth of research on climate change and agriculture that has been conducted at the nearby land-grant university (University of California, Davis), through partnerships with local farmers, cooperative extension, non-profit organizations and local officials.

An essential element of the adaptation process is an understanding that the capacity of a rural community to cope with climate change and other uncertainties will be largely dependent on its collective ability to assemble and process relevant information and then act accordingly (Adger, 2003). Since the impacts of climate change on agriculture will include agronomic, ecological, and socioeconomic dimensions, useful data and knowledge will come from many sources

including scientists, cooperative extension, public officials, NGOs as well as innovative farmers and local businesses. Here we highlight how involvement and insights from these stakeholders in Yolo County have helped to spur planning and action in response to climate change (Figure 1).

Government Initiatives at the State and Local Level

Much of the recent impetus for both research and action on climate change stems from the passing of California's Global Warming Solutions Act in 2006 (Assembly Bill 32; AB32). For example, AB32 now requires local governments to address climate change mitigation in any update to their general plan or to submit a separate climate action plan that does so in detail (CAGO, 2009). The climate action plan recently completed by Yolo County's local government is an early example of what other counties and municipalities will carry out in the not so distant future (Yolo CAP, 2010). Yolo County's climate action plan consists of three main components; 1) an inventory of greenhouse gas emissions (GHG) for 1990 and the current period; 2) a set of local policies to mitigate future emissions; and 3) a section examining possible adaptation strategies to help county stakeholders cope with the local impacts of climate change.

Since the jurisdiction of Yolo County's government is limited to the mostly rural "unincorporated" parts of the county, insights and feedback from the agricultural community were crucial to the planning process. To facilitate this dialog, Yolo's Planning Department held a series of rural stakeholder meetings where available data on agricultural emissions sources and mitigation strategies were discussed with local farmers, the county's agricultural commissioner, cooperative extension, university scientists and others. Table 1 shows the range of GHG emissions sources and while table 2 presents mitigation strategies addressed during these meetings and highlights some of the tradeoffs and co-benefits articulated by the participants.

While examining the county's data on GHG emissions, perhaps the most important observation made by local stakeholders was that electricity use and transportation in neighboring urban areas leads to emissions rates that are roughly 70 times higher per acre than agricultural land uses (Table 3). The intent here was not to shift the emphasis away from the mitigation opportunities within agriculture, but rather to highlight how local policies to promote "smart growth" and protect prime farmland from urbanization may actually help stabilize and reduce future emissions from other sectors. This is particularly relevant in regions of the Central Valley which face mounting pressure to convert farmland to urban land uses. More importantly the concept seemed to establish valuable common ground with those in the agricultural community. Unlike California's industrial sector, AB32 does not require agricultural producers to report their emissions or to implement mandatory mitigation measures (CARB, 2008). The state is however encouraging farmers to institute voluntary mitigation strategies through various public and private incentive programs (Niemeier and Rowan, 2009). That said, some in the agricultural community are still concerned that the policy for agriculture could shift from voluntary to mandatory mitigation at some point in the future, which could make it more difficult for farmers to stay in business. Given that this hypothetical shift in climate policy might inadvertently accelerate farmland conversion and further boost urban emissions, there appears to be a sound case for maintaining and protecting agriculture's voluntary mitigation status.

Tapping into Farmers' Ideas on Mitigation and Adaptation

Protecting farmland from urban conversion is an important first step, because it expands the opportunities to mitigate future emissions, and perhaps more importantly helps to maintain our economic and ecological resilience to the impacts of climate change. But for these goals to be fully realized local farmers and land managers must be part of the process. Farmers have a key role to play since they have vast practical knowledge on how to optimize farm management to reduce agricultural emissions, conserve water or store carbon in the agricultural landscape (Figure 2). Almond orchards in Yolo County are a prime example; reports from some local growers indicate that innovations in drip irrigation have allowed some to reduce N fertilizer applications by up to 30%, while also boosting yield and water use efficiency. Since N₂O emissions from fertilizer use are the single largest source of emissions from agriculture, efforts by growers and commodity boards (e.g. California Almond Board) to expand the use of these technologies have already begun to yield mitigation benefits.

Given that local (and global) temperatures are expected to rise even if the state's mitigation targets are met, it is equally important for rural communities to consider ways to adapt local agricultural systems to the possible impacts (Figure 2, Figure 3). With this in mind, understanding how farmers have adapted to past extreme events (e.g. heat-waves, droughts, floods) can often give insight about what strategies might be effective in the future. For example, during previous droughts Yolo farmers reduced rice and alfalfa acreage (both of which require a lot of water) but increased the cultivation of rain-fed winter wheat. Another planning strategy is to simply look at what farmers are growing just a few hundred miles to the south. By the end of the century the climate in Yolo County is expected to resemble the current climate in Merced County (Jackson et al., 2011). Consequently, Yolo may become better suited for the more heat-tolerant crops commonly found there like olives, citrus and melons.

Bridging the Gap Through Research and Extension

To support these local efforts, an interdisciplinary group of researchers from UC Davis is working on a case study for the California Energy Commission to explore planning scenarios that support the sustainability of agriculture and its adaptation to climate change in Yolo County. The purpose of the project is to create a planning template for other California counties where knowledge on agricultural impacts and solutions are assembled and then made widely available to the public through an interactive website. A key component of this has been the development of three planning tools that will help local land managers and decision makers consider what land-use and adaptation strategies might be useful. The first is a water evaluation and planning (WEAP) model, which assesses how future climatic and economic projections will impact the local water supply and also test the efficacy of various mitigation and water conservation strategies. The second is an urban growth model called UPLAN, which will allow decision-makers to see how future urbanization scenarios might impact the county's farmland and greenhouse gas emissions. The final element has been the development of a survey, which solicits farmers' ideas and perspectives on proposed mitigation and adaptation strategies (Figure 2, Figure 3).

Conclusion

In addition to assembling the information and tools necessary for decision-making one of the main role of this UC Davis research project has been to serve as a bridge between the various stakeholders. Uncertainty is an inherent part of climate change planning. However, by helping

people to express their views and concerns about these uncertainties important social linkages within the community are also strengthened. Better communication in turn increases the ability to come to a consensus on the uncertainties, risks and opportunities posed by the various factors that drive change. Ultimately, communities with strong linkages among those in the social network are bound to have better adaptive capacity in response to change. While this planning process remains in its early stages, there appear to be many good reasons for optimism in Yolo County. Not the least of which is a recognition that the stakeholders mentioned above are committed to strengthening the resilience of Yolo's agricultural landscape to the many changes that lie ahead, be they climate-driven or otherwise.

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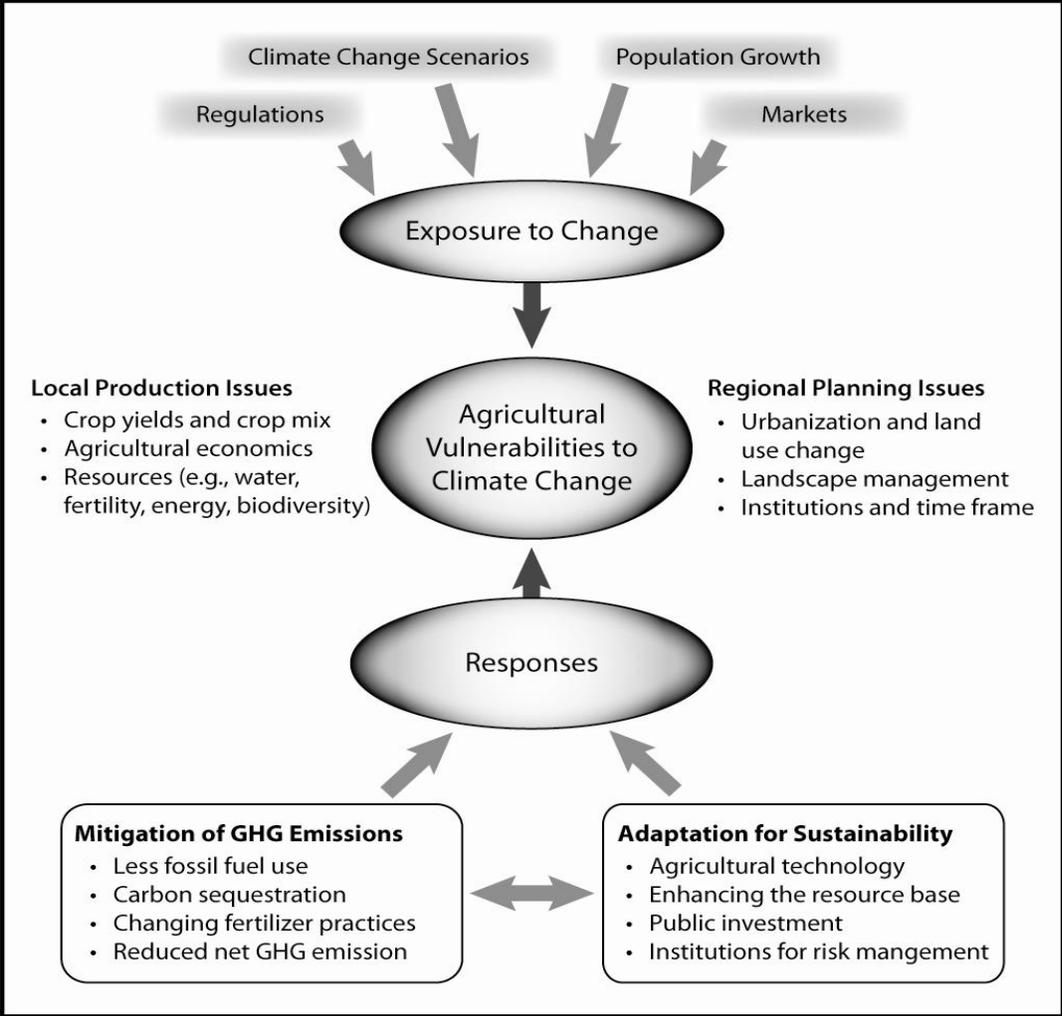


Figure 1. A diagram of potential agricultural vulnerabilities and responses to various change factors including climate change, population growth, markets and regulations. Adapted from Jackson et al. (2011).

Table 1. Summary of Yolo County agricultural CO₂, N₂O and CH₄ emissions (Kt CO₂e) for 1990 and 2008, by source category. Estimates were made using tier 1 methods, activity data based on local agricultural practices, and default emission factors. For detailed methods see supplementary material.

| Source Category | 1990 Emissions | | | | | 2008 Emissions | | | | | Change since 1990 |
|-----------------------------------|----------------------------------|------------------|-----------------|---------------|--------|----------------------------------|------------------|-----------------|---------------|--------|-------------------|
| | CO ₂ | N ₂ O | CH ₄ | Total | Annual | CO ₂ | N ₂ O | CH ₄ | Total | Annual | |
| | ----- Kt CO ₂ e ----- | | | | % | ----- Kt CO ₂ e ----- | | | | % | % |
| Direct N ₂ O from soil | --- | 126.55 | --- | 126.55 | 37.0 | --- | 97.27 | --- | 97.27 | 31.8 | - 23.1 |
| Indirect N ₂ O | --- | 36.43 | --- | 36.43 | 10.7 | --- | 26.68 | --- | 26.68 | 8.7 | - 26.8 |
| Mobile farm equipment | 71.00 | 0.57 | 0.21 | 71.78 | 21.0 | 69.43 | 0.55 | 0.21 | 70.19 | 23.0 | - 2.2 |
| Irrigation pumping | 39.16 | 0.31 | 0.12 | 39.59 | 11.7 | 40.54 | 0.32 | 0.12 | 40.98 | 13.5 | 3.5 |
| Livestock ^a | --- | <i>10.64</i> | 26.53 | 26.53 | 7.8 | --- | <i>12.39</i> | 31.84 | 31.84 | 10.5 | 20.0 |
| Rice cultivation | --- | --- | 25.92 | 25.92 | 7.7 | --- | --- | 31.16 | 31.16 | 10.2 | 20.2 |
| Residue burning ^b | --- | 4.86 | 1.76 | 6.61 | 2.0 | --- | 1.59 | 0.83 | 2.42 | 0.8 | - 63.4 |
| Lime | 4.35 | --- | --- | 4.35 | 1.3 | 2.32 | --- | --- | 2.32 | 0.8 | - 46.7 |
| Urea | 4.15 | --- | --- | 4.15 | 1.2 | 3.46 | --- | --- | 3.46 | 1.1 | - 16.7 |
| Total | 118.66 | 168.71 | 54.54 | 341.92 | | 115.74 | 126.41 | 64.16 | 306.31 | | - 10.4 |

^aN₂O from N excreted by livestock (in italics) is assumed to be applied to soil as manure or urine, thus it is only included in the totals for direct and indirect N₂O.

^bCO₂ emissions from residue burning (104.92 Kt in 1990 and 42.69 Kt in 2008) is considered a biogenic emission, thus was not included in the total.

Table 2. Stakeholder generated trade-offs and co-benefits of various agricultural GHG mitigation strategies in Yolo County.

| Emissions Category | Strategy | Trade-offs | Co-benefits |
|--|------------------------------|---|---|
| Direct and Indirect Nitrous Oxide from Agricultural Soil (N ₂ O) | N fertilizer rate reduction | -yield loss for some crops -already optimized for some crops | -lower input costs -water quality |
| | organic farming methods | -organic fertilizer costs -labor costs -limited pest control options -yield loss for some crops | -price premium -local or direct marketing -environmental quality -agrobiodiversity |
| | cover cropping | -cost of crop establishment -additional fuel use -not compatible with all crop rotations -spring incorporation constraints | -erosion and runoff control -better soil water quality -agrobiodiversity |
| Mobile Farm Equipment (CO ₂ , N ₂ O, CH ₄) | equipment maintenance | -maintenance cost -generally done already | -lower fuel costs |
| | optimize draw-bar load | -generally done already | -lower fuel costs |
| | conservation tillage | -not compatible with all crop rotations | -lower fuel costs and less labor -less wear on tractors -soil carbon sequestration -water conservation |
| | engine upgrades or retrofits | -cost of new equipment | -lower fuel costs |
| Irrigation Pumping (CO ₂ , N ₂ O, CH ₄) | Maintain pump bowl assembly | -maintenance cost -generally done already | -lower fuel or electricity costs |
| | solar-powered pumps | -cost of photovoltaic cell -limited to low horsepower engines -limited to daytime use | -lower fuel or electricity costs |
| Livestock (CH ₄) | biogas control systems | -cost of building the system -engines subject to air quality rules. | -energy generation (gas or electricity) -sale of carbon credits |
| Rice Cultivation (CH ₄) | baling and removal of straw | -baling costs -limited market for rice straw -impacts quality of waterfowl habitat | -sale of rice straw -feed and bedding for livestock -feedstock for biomass power generation |
| | reduce winter flooding | -poor decomposition of straw -impacts quality of waterfowl habitat | -lower pumping costs, fuel savings |
| | mid-season drainage | -crop water stress -yield loss | -control of aquatic weeds -water conservation |

| | | | |
|---|--|--|---|
| Residue Burning (CO ₂ , N ₂ O, CH ₄) | minimize burning | -low overall mitigation potential -already regulated | -air quality |
| Carbon Sequestration (CO ₂) | reforest rangelands, riparian zones and hedgerows | -cost of establishment -require irrigation in early years | -water quality -erosion control -biodiversity |

Table 3. Land area and average emissions rates (MT CO₂e acre⁻¹ yr⁻¹) for rangeland and irrigated cropland and urbanized land in Yolo County during 1990 and 2008. (Haden et al., paper in preparation)

| Land-use Category | Land Area | | Average Emissions Rate | |
|--------------------|-------------------|---------|--|------|
| | 1990 | 2008 | 1990 | 2008 |
| | ----- acres ----- | | --- MT CO ₂ e acre ⁻¹ yr ⁻¹ --- | |
| Rangeland | 131,945 | 135,717 | 0.28 | 0.32 |
| Irrigated Cropland | 344,335 | 324,654 | 0.87 | 0.80 |
| Urbanized Land* | 22,471 | 29,881 | 61.50 | -- |

*Average emissions rates from urbanized land in 2008 are not yet available

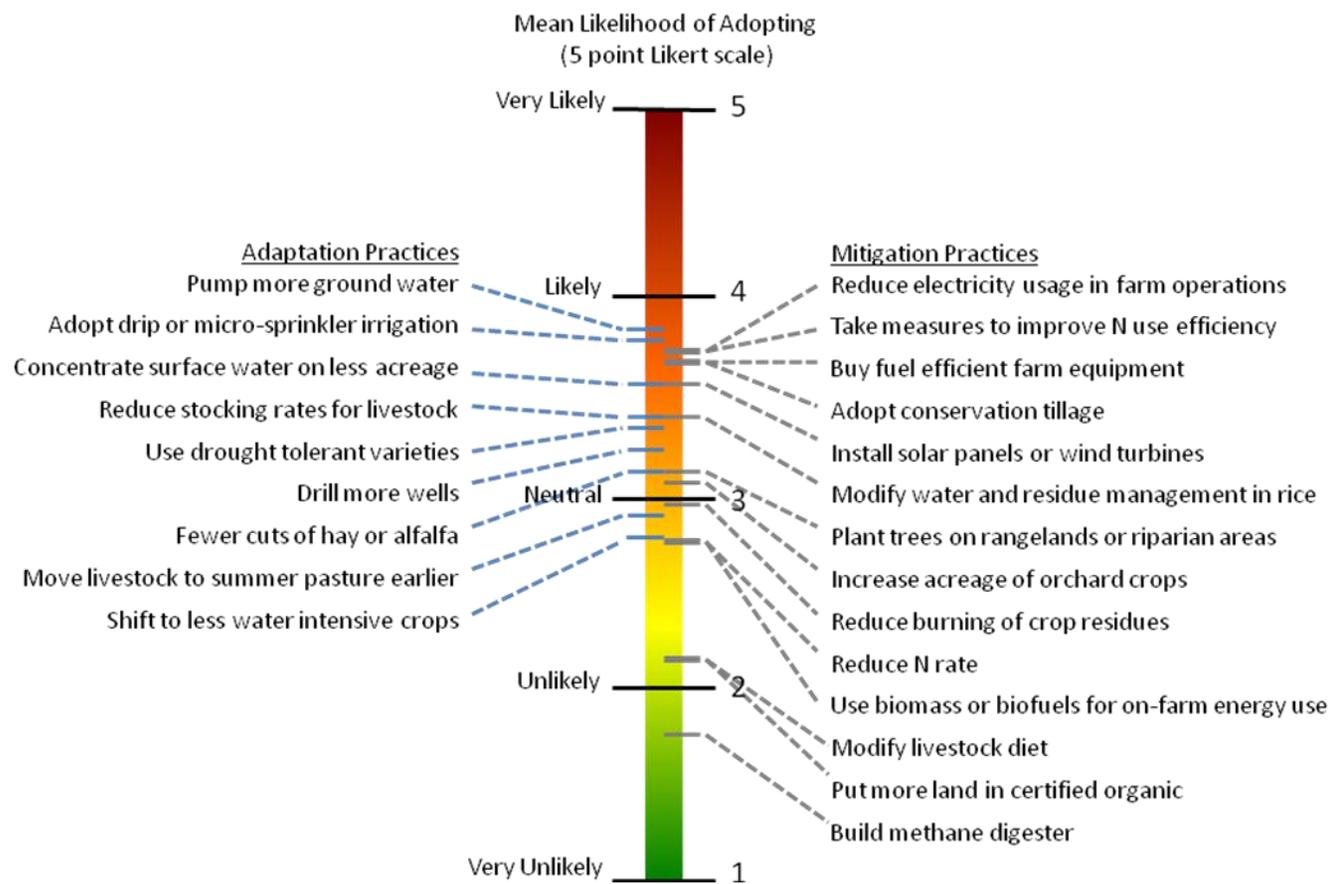


Figure. 2. Mean likelihood of farmers adopting various mitigation and adaptation practices.

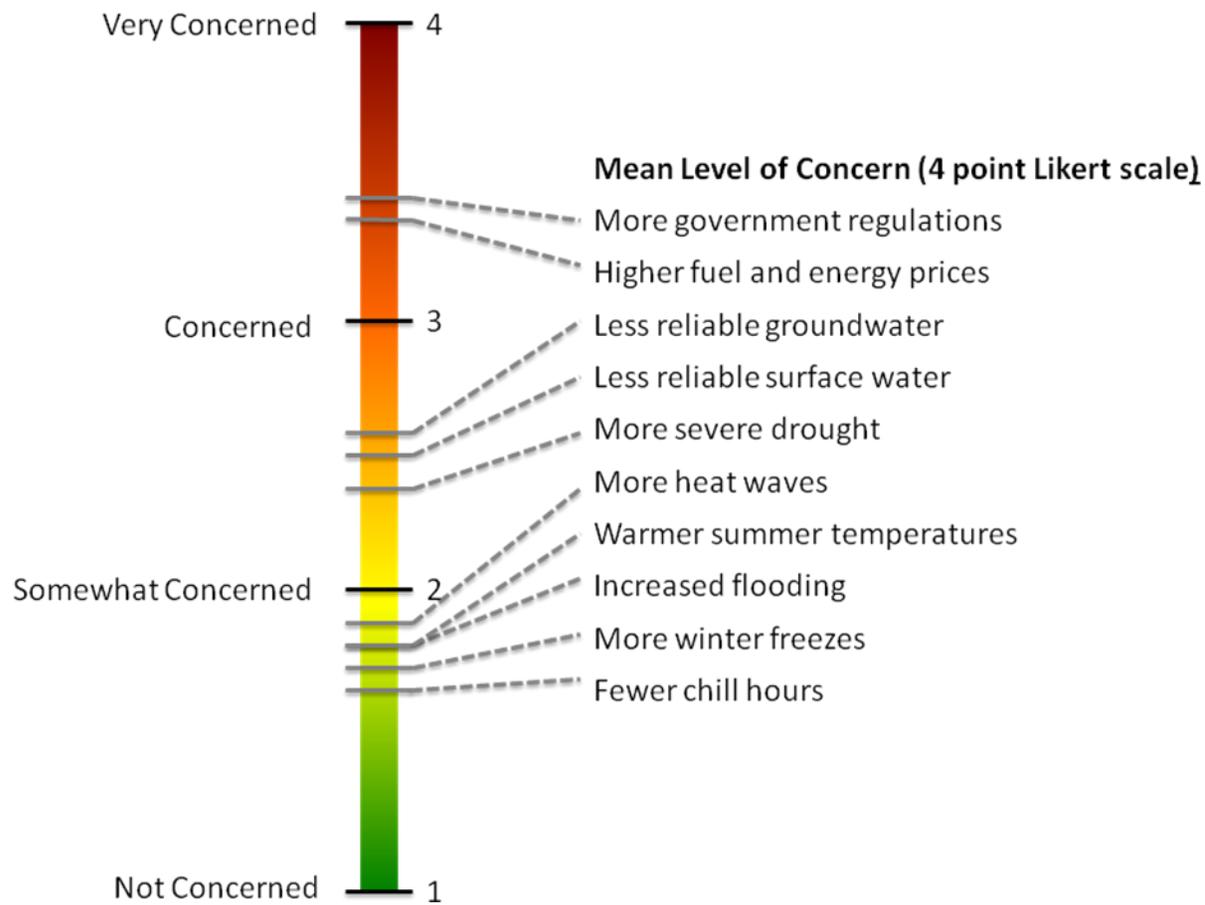


Figure. 3. Mean level of concern regarding local climate related impacts among Yolo County farmers

A Department of Pesticide Regulation Update

Matt Fossen
CA Department of Pesticide Regulation
Pest Management and Licensing Branch
1001 I Street, P.O. Box 4015
Sacramento, CA 95812
(916) 322-1747- Office
mfossen@cdpr.ca.gov

NOTES & QUESTIONS:



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Optimizing Drip Irrigation Systems for Alfalfa Seed Production in the Central San Joaquin Valley

Shannon Mueller, Agronomy Farm Advisor, UC Cooperative Extension, 1720 S. Maple Avenue, Fresno, CA 93702. Phone: (559) 600-7233, Email: scmueller@ucdavis.edu

Larry Schwankl, Irrigation Specialist, Dept. of Land, Air, and Water Resources, UC Davis, based at the Kearney Ag Center, 9240 S. Riverbend Avenue, Parlier, CA 93648.
Phone: (559) 646-6569, Email: schwankl@uckac.edu

Bob Hutmacher, Extension Cotton Specialist and Director UC West Side Research and Extension Center, P.O. Box 158, Five Points, CA 93624.
Phone: (559) 884-2412, Email: rbhutmacher@ucdavis.edu

Introduction

California is the largest producer of alfalfa seed in the United States with major production areas located in Fresno, Kings, and Imperial Counties. Irrigation management is critical to the success of the production system. Both the timing and the amount of water applied during an irrigation can greatly affect the condition of the field, pollinator activity, and subsequent seed production. Controlled moisture stress is standard practice in the management of alfalfa for seed production. Growers attempt to stress the alfalfa to encourage pollination of existing bloom while still providing enough moisture to promote continuous regrowth from the crown. It is often difficult to achieve this balance.

In the Central San Joaquin Valley, alfalfa seed production requires approximately 3.5 to 4 acre-feet of water either as irrigation or effective rainfall. First year fields may require less, on the order of 3 acre-feet. Currently, most irrigation systems are surface systems – flood or furrow; drip irrigation (SDI) systems are rare. There have been efforts to develop drip irrigation strategies for alfalfa seed production in the West, but the practice is still not common. In the early 1990s, Jeff Steiner and Bob Hutmacher (USDA) conducted studies at the UC West Side Research and Extension Center (WSREC) to evaluate alfalfa seed production under drip irrigation. More recently, a few pro-active growers on the west side of Fresno County in the Central San Joaquin Valley have incorporated drip irrigation into their production systems. They have demonstrated that it is possible to produce a crop on approximately half of the water typically used to grow seed alfalfa. Their success has prompted renewed interest from the grower community to learn more about the viability and management of drip irrigation systems for alfalfa seed production. There is also greater incentive and support for research efforts due to water shortages resulting from weather-related drought conditions and redistribution of water for environmental and municipal use. Demand for alfalfa seed remains strong, and if water use could be reduced, viability of seed production as a rotation option for California growers improves.

Materials and Methods

An alfalfa seed field was established in March 2010 to evaluate planting configurations and drip irrigation management to maximize seed yield. The variety planted was ‘Pioneer 59N49’ and the trial area was sprinkler irrigated during the stand establishment period. There were two planting configurations – a single row of alfalfa on a 30” bed was compared with two rows of alfalfa on a

60" bed. The two rows were planted approximately 30" apart. In both planting configurations, a single line of drip tape was installed 10-12" deep in the center of the beds. The drip tape used was Netafim Streamline tape with 0.24 gph emitters spaced every 12". There were four irrigation regimes where plots were irrigated at 25%, 50%, 75%, or 100% of crop ET. Plots ran the length of the field (approximately 300'). Potential ET was determined using the CIMIS weather station located on the West Side Research and Extension Center approximately 1/3 mile from the alfalfa trial site.

Irrigation applications were closely monitored throughout the season using flow meters to measure the amount of water applied. Levels of plant water stress associated with the irrigation treatments were monitored using infrared thermometry. All other crop management practices reflected typical commercial operations. Weed and insect pest populations were monitored and controlled throughout the season using standard treatments. Honey bees were introduced for pollination at the appropriate time and density. Plots were desiccated and then harvested with a small 2-row research combine and seed yield was analyzed using standard ANOVA procedures for a split plot design with planting configuration as the main plot and irrigation treatment as a sub-plot within the main plot. There were four replications of each treatment.

Infrared Thermometry and Crop Water Stress Index with Deficit Irrigation

Measurements were taken on plants to identify levels of plant water deficits developing within each of the four subsurface drip irrigation treatments. For the purposes of this description of plant water stress as affected by irrigation level/treatment, data will be described only for measurements made in the double-row 60 inch bed configurations. The planted rows were in a north-south orientation.

Prior work done by Hutmacher established non-stressed and fully-water stressed baselines used to determine the relationship between the value (crop canopy temperature (T_c) minus air temperature) in degrees C versus the actual vapor pressure deficit of the air, in kPa (Hutmacher et al, 1991). Work conducted as part of this field study compared those older non-stressed baselines with calculations using data from this current study, and those will be discussed. The canopy temperature was determined using an Extech Hand Held infrared thermometer, while the air temperature and relative humidity needed to calculate actual vapor pressure were determined using a hand-held aspirated thermohygrometer.

The thermohygrometer measurements were made within the field at a position 2 to 3 feet above the alfalfa canopy at 10 minute intervals during the course of associated infrared thermometer readings. The infrared thermometer had a distance:spot ratio of 12:1 and was set for an emissivity of 0.97. A minimum of 6 readings per plot were made while walking down plot rows, at a distance of about 15 to 20 feet between readings. As many as 10 readings per plot were made in the more stressed treatments in the late season due to variability noted between readings. The infrared thermometer was held at an angle of about 25-30 degrees below horizontal during readings, and pointed in a northwest direction across the beds.

Crop water stress index was calculated using the method of Idso (1982). In general, values of the crop water stress index (CWSI) that are close to a value of "0" indicate well-watered, non water-stressed plants, while very water-stressed plants would have CWSI values closer to a value of "1", indicating that the crop canopy temperature was approaching that expected for a non-transpiring, highly water-stressed plant canopy.

Measurements were made during 1300 to 1530 hours PDT during generally cloud-free days during the period from June through the first of September. Preliminary presentation of the data from this first year of the trial in this paper only shows average values. Later work will be done to provide a more detailed statistical evaluation of the data.

Summary of Irrigation Results

Primary among the changes in irrigation practices when using SDI is the frequent irrigation applications, often daily in this experiment. Each irrigation replaces the soil water withdrawn to satisfy the previous day's ET demands. This contrasts with the infrequent but large applications of water applied with a surface irrigation system.

The first year of the project showed the SDI to be potentially very efficient in applying water. Crop water use (ET) at Five Points during the trial period (7 July to 8 September 2010) was 17.4 inches. The water applied via subsurface drip irrigation (SDI) to the 100% ET treatment was 14.8 inches. The additional water to meet crop ET was supplied by stored soil moisture from winter rains (approximately 9.5 inches during the previous winter) and sprinkler irrigations applied during stand establishment (4.25 inches). Stored soil moisture was also available to supplement the irrigation amounts applied in the 25%, 50%, and 75% ET treatments. The actual SDI-applied water for the four irrigation treatments was as follows:

| Target Treatment | Irrigation Water Applied (in.) | % of Full ET Treatment |
|------------------|--------------------------------|------------------------|
| 100% ET | 14.8 | 100 |
| 75% ET | 10.6 | 72 |
| 50% ET | 6.0 | 40 |
| 25% ET | 2.5 | 17 |

Note that the actual applied water was slightly less than the target ET treatments, which is not unusual and occurs due to pressure and flow fluctuations of the SDI system.

Summary of Results from Plant-based Measurement of Crop Water Stress

Crop Water Stress Index (CWSI) values across the different irrigation treatments did not show much variation prior to mid-July, after which the differences between the lowest two irrigation treatments (25% and 50%) and the higher irrigation treatments (75% and 100%) became more consistent and larger in CWSI value. In the second half of August, the CWSI values for the lowest irrigation treatment (25%) started to separate out from those measured in the 50% treatment. Continued evaluation of this measure in future years will hopefully lead to the ability of the CWSI/Infrared thermometry approach to describe levels of plant water stress in seed alfalfa and improve irrigation management.

The non-stressed and fully-water stressed baselines for the relationship $T_c - T_a$ versus VPD, where T_c = canopy temperature (in degrees C), T_a = air temperature (in degrees C), and VPD = vapor pressure deficit (in kPa) determined using measurements in this field trial were:

Non-stressed baseline: $T_c - T_a = (-1.381 * VPD) + 0.67$

Fully-stressed baseline: $T_c - T_a = (0.1459 * VPD) + 1.51$

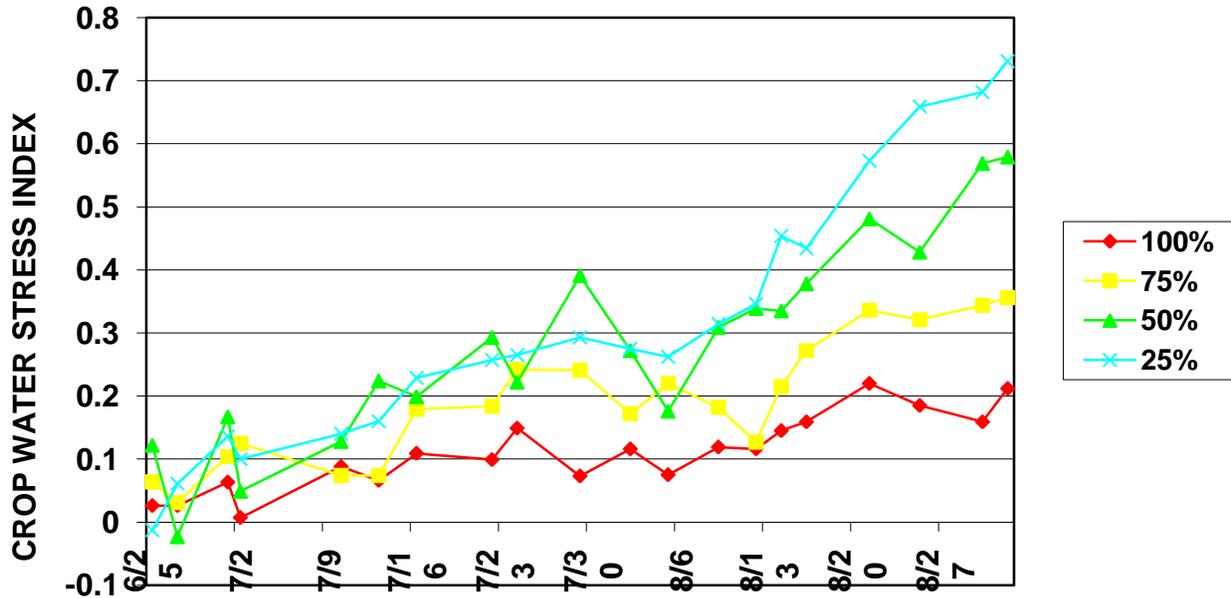


Figure 1. Crop water stress index (CWSI) values as a function of day of year (X-axis) and irrigation treatment (% values shown in legend) from afternoon infrared thermometry readings in seed alfalfa subsurface drip irrigation experiment at the West Side Research and Extension Center near Five Points, CA in 2010.

From prior work in which we evaluated stomatal conductance values in combination with CWSI calculations, we have found that CWSI values greater than 0.3 to 0.4 represent some significant reductions in crop water use rates that are reflected both in warmer leaf or plant canopy temperatures and in lower stomatal conductance (Hutmacher et al, 1991). In the second half of August, the CWSI values for the lowest irrigation treatment (25%) started to separate out from those measured in the 50% treatment.

The non-stressed baselines for the Tc-Ta versus VPD relationship measured in this study were relatively comparable to the baselines determined in our earlier study (Hutmacher et al, 1991). This seems to be a fairly positive sign, as the earlier data was taken with a different set of instrumentation many years prior. Further evaluations will assist us in determining the relative consistency of the CWSI measurements made across dates and years, and during future growing seasons we plan to compare CWSI measurements with leaf water potential measurements made on select dates and irrigation treatments to further define the ability of the CWSI / Infrared thermometry approach to describe levels of plant water stress in seed alfalfa.

Table 1. Non water-stressed baselines for the Tc-Ta versus VPD relationship measured in the current study versus prior studies of Hutmacher et al (1991).

| Year of evaluation | Slope for non water-stressed baseline equation | Intercept for same equation | r ² value |
|--------------------------|--|-----------------------------|----------------------|
| 2010 | -1.38 (flowering to pod fill period) | 0.67 | 0.68 |
| First year – prior study | -1.42 (flowering to pod fill period) | 0.58 | 0.87 |
| Third year – prior study | -1.12 (flowering to pod fill period) | 0.62 | 0.70 |

Summary of Yield Results

Yield data from this trial is presented in Table 2 and Figure 2. There was no significant interaction between planting configuration and irrigation treatment. There was no significant difference in yield per acre when the single-row 30” planting was compared with the double row on a 60” bed (581 vs. 549 lb/A). There was also no significant difference in yield among the four irrigation regimes where plots were irrigated at 17%, 40%, or 72%, of the full ET treatment, although the trend was for higher yields with greater amounts of water.

Table 2. Yield of clean seed (pounds/acre) from seed alfalfa subsurface drip irrigation experiment at the West Side Research and Extension Center, Five Points, CA in 2010.

| Planting Configuration | Irrigation Treatment Target (Actual % of Full ET treatment) | | | | Averages w/in Planting Configurations |
|--|--|-----------------|-----------------|---------|---|
| | 25% ET (17%) | 50% ET (40%) | 75% ET (72%) | 100% ET | |
| Single Row, 30” Bed | 523 | 556 | 570 | 674 | 581 |
| Double Row, 60” Bed | 489 | 574 | 607 | 525 | 549 |
| <i>Averages w/in Irrigation Treatments</i> | 506 | 565 | 588 | 599 | |

CV (%) = 19.53%

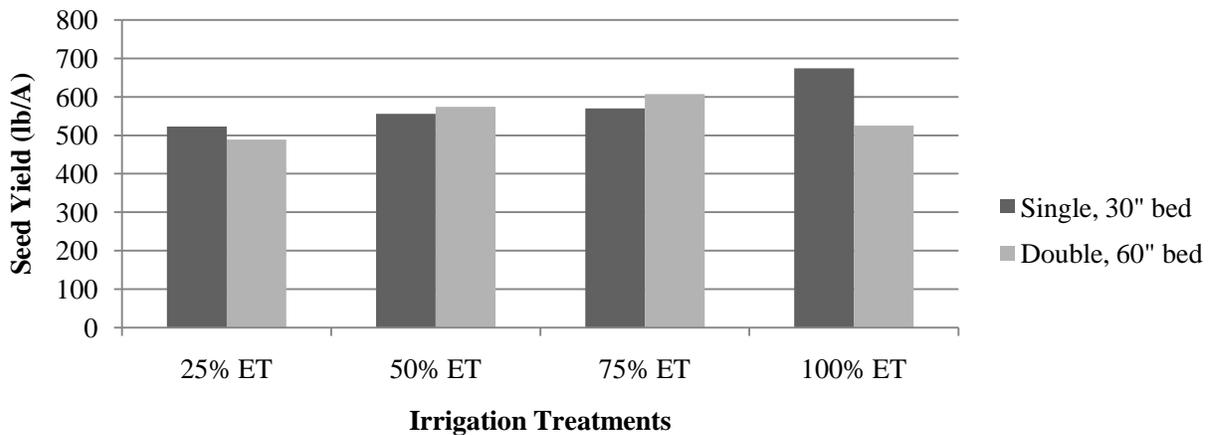


Figure 2. Yield of clean seed (lbs/acre) from seed alfalfa subsurface drip irrigation experiment at the West Side Research and Extension Center, Five Points, CA (2010).

Discussion

Because there was no difference in seed yield associated with planting configuration the first year, results suggest producing alfalfa seed on either a 30” or 60” bed spacing with SDI can be left to grower preference. Since twice the amount of tape is required to install SDI on fields with 30” beds compared to 60” beds, demonstrating no yield reduction from production on a 60” bed using SDI is important. Adding another crop, seed alfalfa, to the list of rotation options a grower can consider for fields with drip irrigation systems is a benefit because amortizing the cost of

materials and installation across as many years of the rotation as possible improves the economic feasibility. Drip irrigation systems are expensive, and the advantage is greatest where water is expensive and/or limited.

With respect to irrigation, in the establishment year there was no difference in seed yield when plots were irrigated at 17% of the amount provided to the 100% ET treatment. It is hypothesized that this occurred because the substantial stored soil moisture, from winter rains and sprinkler irrigation used for establishment, provided sufficient water to meet crop ET demands. Five hundred pounds of seed per acre were produced with 6.75" of applied water (sprinkler and SDI). This is less than 50% of the typical recommendation for a first year field of 3 acre-feet of moisture supplied by effective rainfall and surface irrigation. A significant water savings was achieved without a reduction in yield compared to the well-watered treatment.

In addition to its efficiency, another potential advantage of the SDI system is the capability of imposing the desired water stress to encourage the setting of seed. It is well-known that alfalfa is typically stressed in order to promote seed production. The SDI system should result in a more limited wetted soil volume as compared to a surface irrigated field. The limited stored soil moisture would be used up more quickly once water is cut off. This gives a manager the capability of imposing water stress more quickly and with greater control. With surface irrigation systems such as flood and furrow, there is less control. The *frequency* of irrigation can be adjusted, but the *amount* of water applied in a given irrigation is less flexible because a given amount of water is required to reach the end of the field and application and distribution uniformity is lower.

It is risky to base recommendations on a single year of observations. Information on an established crop would be helpful as would information on the contribution of stored soil moisture to meeting crop ET needs. This would be accomplished by gathering pre- and post-season soil moisture samples and continuous soil moisture monitoring using Watermark soil moisture block stations in each of the treatments. This trial was to be repeated in 2011 with modification of the ET thresholds for irrigation and greater monitoring of soil moisture status, pollinator activity, plant response, and seed quality in order to begin to develop guidelines for growers interested in producing seed alfalfa under drip irrigation. Unfortunately, due to extreme gopher pressure resulting in countless leaks and the inability to control the water within treatments, the field was taken out of production.

SDI Use Considerations

Just a single year's use of the SDI system identified some important considerations in its use in a seed alfalfa system. They include:

1. The water supply for the project was Westlands Water District. While the water delivery by Westlands is primarily a pressurized pipeline system, the water source is a surface water source. By the end of the irrigation season, the water carries a significant organic contaminant load. High quality filtration, periodic chlorination, and regular line flushing is important to maintain the SDI system.
2. Rodent damage can be a significant threat to successful use of SDI in seed alfalfa. The seed alfalfa is an attractive food source for gophers. More importantly though, SDI use eliminates flooding as a gopher control mechanism and seed alfalfa is an extremely difficult crop in

which to detect tape damage by gophers. The nearly full coverage is hard to walk through and it is difficult to spot system leaks. The bottom line is that gopher control is essential or the SDI production system use will not be successful.

While there were a limited number of gopher strikes in an adjacent trial which had drip tape installed at both 12" and 18", the gopher damage occurred on the 12" deep drip tape. This may indicate that the 18" deep tape is less likely to be damaged by gopher activity. Deeper tape installation may therefore be advantageous in reducing gopher damage, but any damage that occurs on 18" deep drip tape would be significantly more difficult to repair. At this stage, the lesser gopher damage to 18" tape should be considered a possible trend rather than an established fact.

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Subsurface Drip Irrigation in Alfalfa Hay

Khalid Bali, Farm Advisor
UC Cooperative Extension, Imperial County
1050 East Holton Road
Holtville, CA 92250-9615
(760) 352-9474 Ext.28
kmbali@ucdavis.edu

NOTES & QUESTIONS:

Improving Water and Nitrogen Efficiency in Lettuce

Michael Cahn, Irrigation and Water Resources Advisor
U.C. Cooperative Extension, Monterey County
1432 Abbott St. Salinas CA 93901
(831) 759-7377 fax (831) 758-3018 mdcahn@ucdavis.edu

Richard Smith, Vegetable and Weed Advisor
U.C. Cooperative Extension, Monterey County
1432 Abbott St. Salinas CA 93901
(831) 759-7365 fax (831) 758-3018 rifsmith@ucdavis.edu

Introduction

Ground water on the central coast of California frequently has nitrate-N concentrations above the drinking water standard of 10 mg L⁻¹ in regions intensively farmed with cool season vegetables. To assure high yields and quality of lettuce, growers typically apply rates of fertilizer N greater than crop uptake and more irrigation water than the consumptive use requirement of the crop. The combination of a shallow root system and over application of water can potentially leach 30% to 50% of applied N during the growing season. In addition, 2 to 3 vegetable crops are usually grown per field during a season, often resulting in the build-up of mineral nitrogen in the soil by the fall and subsequent leaching of nitrate-N during winter storm events. Current state water quality regulations require growers to minimize the discharge of nitrate to ground and surface water supplies. The draft agricultural order for the central coast will require large vegetable operations (> 200 ha) to develop and implement irrigation and nutrient management plans, certified by a professional agronomist or crop consultant. Under the agricultural order, growers will be expected to demonstrate improvements in N and water use efficiency in their farming operations during the next 5 years. One of the measures of success that growers will need to demonstrate is that the amount of fertilizer-N applied is in parity with amount of N taken up by the crop. During the previous 5 years, we have evaluated best management practices for improving water and N use efficiency of lettuce in commercial fields and minimizing nitrate leaching losses. The two main approaches that were most successful were: 1. field testing of soil mineral N to determine appropriate fertilizer-N rates, and 2. optimizing irrigation management

Procedures

We conducted 5 replicated trials in commercial lettuce fields during the 2008 and 2009 seasons to compare grower practices to a best managed practice (BMP) which included the use of the quick soil nitrate test for determining N fertilizer requirements and scheduling irrigations using daily CIMIS evapotranspiration data and a water use model for lettuce. Trials were conducted in 6 to 11-ha fields, having soil textures ranging from silty clay to sandy loam in locations ranging from Salinas to San Ardo. Iceberg lettuce was grown at 2 of the trials and romaine was grown at the other 3 trials. Strips of 49-m in width × field length were managed by the growers' standard practice or using the BMP treatment. Treatments were replicated 3 times. Marketable yield was estimated in small plots and using a commercial harvester for the entire strip length. We also conducted 6 non-replicated trials in commercial lettuce fields during the 2010 season to demonstrate the use of the quick nitrate soil test strip for guiding fertilizer N applications. Five of the trials were planted with iceberg lettuce and one trial was planted with romaine lettuce. A 0.5 to 1-ha strip in each field was fertilized

based on soil-N test results, where 20 ppm of nitrate-N in the soil was considered sufficient for maximizing crop growth. Applied water was monitored at each field using flow meters. Marketable yield was measured in the strip where N fertilizer was managed with the quick nitrate strip and in an adjacent strip, where N fertilizer was managed by the grower's standard practice.

Results

Water and nitrogen fertilizer application were significantly reduced under the BMP regime in the 5 replicated trials, averaging 136 kg of N ha⁻¹ and 29 cm of water compared to an average of 197 kg of N ha⁻¹ and 35 cm of water under the grower standard treatment (Tables 1 and 2). Despite applying less N-fertilizer in the BMP treatment, seasonal soil nitrate concentrations were equal to concentrations measured in the standard treatment. Nitrate-N concentrations of leachate sampled with suction lysimeters 60 cm below the soil surface ranged from 105 to 178 mg L⁻¹ and were not significantly different between treatments; however, estimated losses of nitrate-N were least in the BMP treatment due to improved water management. Marketable yields measured in small plots and also using a commercial harvester were not significantly different between the BMP and standard treatments.

Similar to the replicated trials, using the quick nitrate test reduced N fertilizer rates in the BMP treatment of the non-replicated field trials without causing significant yield loss. Average N fertilizer applied was 247 and 168 kg of N ha⁻¹ for the standard and BMP treatments, respectively (Fig. 1). Applied water for the entire lettuce crop averaged 33 cm and ranged from 13 to 54 cm for the 6 trials. Highest N fertilizer rates were measured at sites with the greatest volume of applied water. Trials where the total applied water closely matched crop ET also had the highest concentrations of soil nitrate in the grower standard treatment at harvest.

Conclusions

The results of the replicated and non-replicated field trials demonstrated that careful water management and nitrogen fertilizer management can result in equivalent yields and save money. In addition, reducing nitrate leaching could minimize nitrogen loading to ground water supplies. The main tool for improving irrigation scheduling for lettuce was using CIMIS evapotranspiration data and water use model for lettuce to estimate a reasonable irrigation schedule that will maintain yields and minimize percolation of nitrate. The nitrate quick test provided accurate guidance for managing fertilizer nitrogen in season. Taken together, these tools can help growers improve nitrogen fertilizer and water management in lettuce production.

Table 1. Applied fertilizer-N, seasonal soil nitrate, and crop N uptake for the grower standard and best managed treatments for 5 replicated trials.

| Trial | Standard | BMP | N Fertilizer Reduction (kg N/ha) | Fertilizer Cost Reduction (\$/ha) ¹ | Standard | BMP | Standard | BMP |
|---------|-------------------------------------|-----|--|---|--|------|---|-----|
| | Total Applied Nitrogen (kg N/ha) | | | | Mean Soil Nitrate (over season) (ppm NO ₃ -N) | | Total N Uptake at Harvest (kg N/ha) | |
| Trial 1 | 278 | 123 | 155 | 202 | 33.3 | 47.0 | 150 | 158 |
| Trial 2 | 86 | 72 | 14 | 18 | 18.3 | 19.5 | 167 | 149 |
| Trial 3 | 224 | 172 | 52 | 67 | 19.5 | 20.4 | 97 | 105 |
| Trial 4 | 202 | 150 | 52 | 68 | 18.7 | 17.7 | 185 | 194 |
| Trial 5 | 196 | 162 | 34 | 45 | 41.3 | 26.9 | 134 | 133 |
| Average | 197 | 136 | 61 | 80 | 26.2 | 26.3 | 146 | 148 |

¹ nitrogen fertilizer valued at \$ 1.3/kg

Table 2. Total applied water for the grower standard and best managed treatments for 5 replicated trials.

| Trial | Standard | BMP | Estimated Crop ETc (cm) | Irrigation requirement ¹ (cm) | Water use reduction (%) | Energy Savings ² (\$/ha) |
|---------|-----------------------------|-------|-------------------------------|--|-------------------------------|---|
| | Total Applied Water (cm) | | | | | |
| Trial 1 | 45.01 | 37.38 | 25.68 | 34.08 | 16.95 | 38.27 |
| Trial 2 | 25.18 | 22.12 | 19.30 | 22.63 | 12.12 | 18.77 |
| Trial 3 | 49.33 | 30.26 | 17.04 | 22.12 | 38.66 | 44.75 |
| Trial 4 | 27.21 | 26.45 | 17.70 | 21.44 | 2.80 | 2.96 |
| Trial 5 | 27.72 | 25.68 | 15.61 | 19.24 | 7.34 | 7.90 |
| Average | 34.89 | 28.38 | 19.07 | 23.90 | 15.57 | 22.53 |

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

² assumes energy costs of \$0.15/kWhr, operating well depths of 22.5 m for south county trials, and 50 m for north county trials

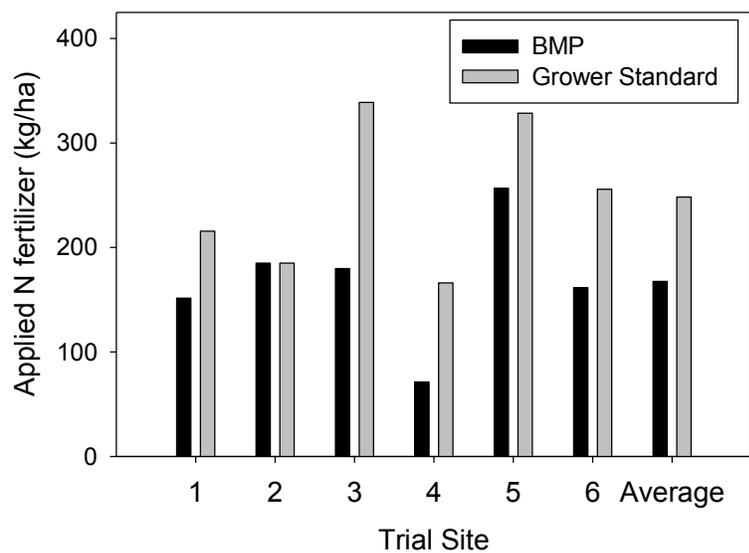


Fig. 1. Fertilizer N rates for best managed and grower standard treatment in non-replicated strip trials in iceberg and romaine lettuce.

Influence of Regulated Deficit Irrigation Strategies Applied to ‘Arbequina’ Olive Trees On Oil Yield and Oil Composition.

Richard C. Rosecrance, Plant Sciences
California State University, Chico
Chico, CA 95929-310

William H. Krueger, University of California Cooperative Extension
Orland, CA 95953

Matt Lohse,
Carriere Family Farms,
Glenn, CA 95963

Introduction

Olive oil production has a long history in southern Europe and traditionally trees were grown under dry-land conditions. Trees were widely spaced to accommodate the lack of water and yields were typically low. During the late 1980s in Spain and Italy, the introduction of irrigation systems and improved methods of training trees enabled growers to move toward much denser plantings. Dense planting of olive trees using such methods began in California in 1999. In just a decade, acreage of super high density olive oil orchards reached 17,000 acres. However, there is little information on production practices of high density olive oil production in California.

Studies in Europe have shown that irrigation can increase olive production (Lavee et al., 1990) thereby increasing total oil production per tree. However, studies have indicated that chemical and sensory characteristics of olive oil decline as applied water increases (Berenguer et al., 2006). Irrigation management can have a profound influence on olive oil production and quality. A recent study determined that optimum oil extraction occurred over a wide range of evapotranspiration (ET) treatments (i.e. ETc 40–89%) however, oil quality was greatest at irrigation levels between 33 and 40% ETc (Gratten et al., 2006). These treatments were applied over the whole growing season, not at specific phenological stages. Regulated deficit irrigation (RDI) is an irrigation strategy to manipulate yield, quality and vegetative growth with water stress at specific phenological stages. Regulated deficit irrigation has been used in some fruit crops to improve water use efficiency, control vegetative growth, and maintain or improve fruit quality. A few regulated deficit irrigation trials with oil olive varieties have been conducted in Europe but no research is available under California conditions. Specific objectives were to quantify the impacts of irrigation treatments on oil production, fruit yield, fruit set, and fruit size. Irrigation effects on the oil quality, both chemical and sensorial will be evaluated.

Methods

We initiated a 3-year study in the summer of 2009 at a large ranch near Artois, California with five year old trees that are drip irrigated. The orchard is planted with the variety ‘Arbequina’ at a high density (1.5 m x 3.9 m). RDI treatments were initiated 2 weeks after pit hardening. The experimental treatments include:

1. Control - 40% Eto
2. 30% Eto
3. 20% Eto
4. Gradual drawn down (two weeks after pit hardening apply 10% less water , 20% two weeks later, and 30% five weeks after pit hardening)

Key Findings

No significant differences were found in mid-day stem water potentials between the treatments in 2010 (Figure 1A). The unusually cool summer in 2010 may have resulted in similar stem water potential readings among the treatments. These stem water potentials are very low, markedly lower than stem water potentials typically found in almond (~ 10-15 bars) and walnut (~3-10 bars) trees. The ability of olive trees to function at low stem water potentials indicates that they are very water use efficient. However, threshold stem water potential values have not been developed for olive trees. Data from the experiment will assist in the development of threshold stem water potential values for olives.

The gravel soils produced significantly lower stem water potentials than in the loam soils over the season (Figure 1B). Interestingly, the gravelly soils are producing greater water stress than the water deficit treatments. Over the whole season, the stem water potentials in the gravelly soils averaged 3.7 bars lower than in the loam soils. These water potential differences between the gravel and loam soils are likely evident throughout the whole season and occur prior to the imposition of the RDI treatments. .

Results from the second year of the study are presented in Table 1. Irrigation treatments ranged from 16.4 inches (40% ETo --Control) to 13.3 inches (20% ETo) of water applied per acre. This difference is only 3.1 inches but equates to over 86,000 fewer gallons of water per acre applied to the 20 % ETo treatment vs. the 40% ETo treatment.

No significant differences were found among the main plot RDI treatments, however many significant differences were found between the soil subplots (Table 1). For example, oil production (gallons/a and gallons/t), percent fat, and poly-phenol concentration (data not shown) were greater in the gravel loam vs. loam soil. However, trunk growth, fruit fresh weight yield, pruning weights, and fruit moisture were greater in the loam vs. gravel loam soil. Thus, gravel loam plots produced significantly more oil, but significantly lower fresh fruit yield than the loam plots (Table 1). The significantly lower moisture content in the fruit of the gravel loam vs. loam soil likely caused this result. These findings are extremely interesting because they suggest that olive oil trees produce more oil in coarse-textured than in fine-textured soils. Unfortunately, most of the recent high-density orchards are planted on fine-textured soils. Finally, few significant main plot effects were found; this indicates that RDI treatment can be imposed without oil yield reductions, can improve oil quality, and reduce pruning costs.

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Table 2. Effects of regulated deficit irrigation on yield, fruit moisture, acidity, fruit weight, shoot and trunk growth, pruning weight, and fat content in 2010¹.

| Treatment | Water Applied (in) | Fruit Yield (lbs/ac) | Oil Yield (gal oil/ac) | Oil Yield Eff. (gal oil/ton) | Fruit Moisture (%) | Acidity | 10 fruit Wt (g) | Shoot Growth (cm) | Trunk Growth (cm) | Prune Wt (lbs) | Fat (%) |
|-------------|--------------------|----------------------|------------------------|------------------------------|--------------------|---------|-----------------|-------------------|-------------------|----------------|---------|
| 40 % Eto | 16.4 | 11029 A | 184 A | 34.2 B | 53 A | 0.13 A | 13.2 A | 1.8 A | 1.09 A | 179 A | 18.8 A |
| 30 % Eto | 14.5 | 10537 A | 178 A | 34.8 B | 53 A | 0.16 A | 13.1 A | 2.1 A | 0.81 A | 138 A | 18 A |
| Taper Eto | 14.8 | 10199 A | 200 A | 37.8 A | 52 A | 0.18 A | 12.4 A | 1.6 A | 0.81 A | 180 A | 19 A |
| 20 % Eto | 13.3 | 10554 A | 190 A | 37 AB | 50 A | 0.12 A | 12.2 A | 0.9 A | 0.24 A | 167 A | 19.1 A |
| | | | | | | | | | | | |
| Gravel loam | | 9981 B | 202 A | 41 A | 49 B | 0.07 B | 12.8 A | 1.1 A | 0.32 B | 101 B | 20.4 A |
| Loam | | 11179 A | 175 B | 31 B | 55 A | 0.23 A | 12.7 A | 1.8 A | 1.65 A | 231 A | 17.1 B |

¹ Different letters indicate significant differences at $p < 0.05$.

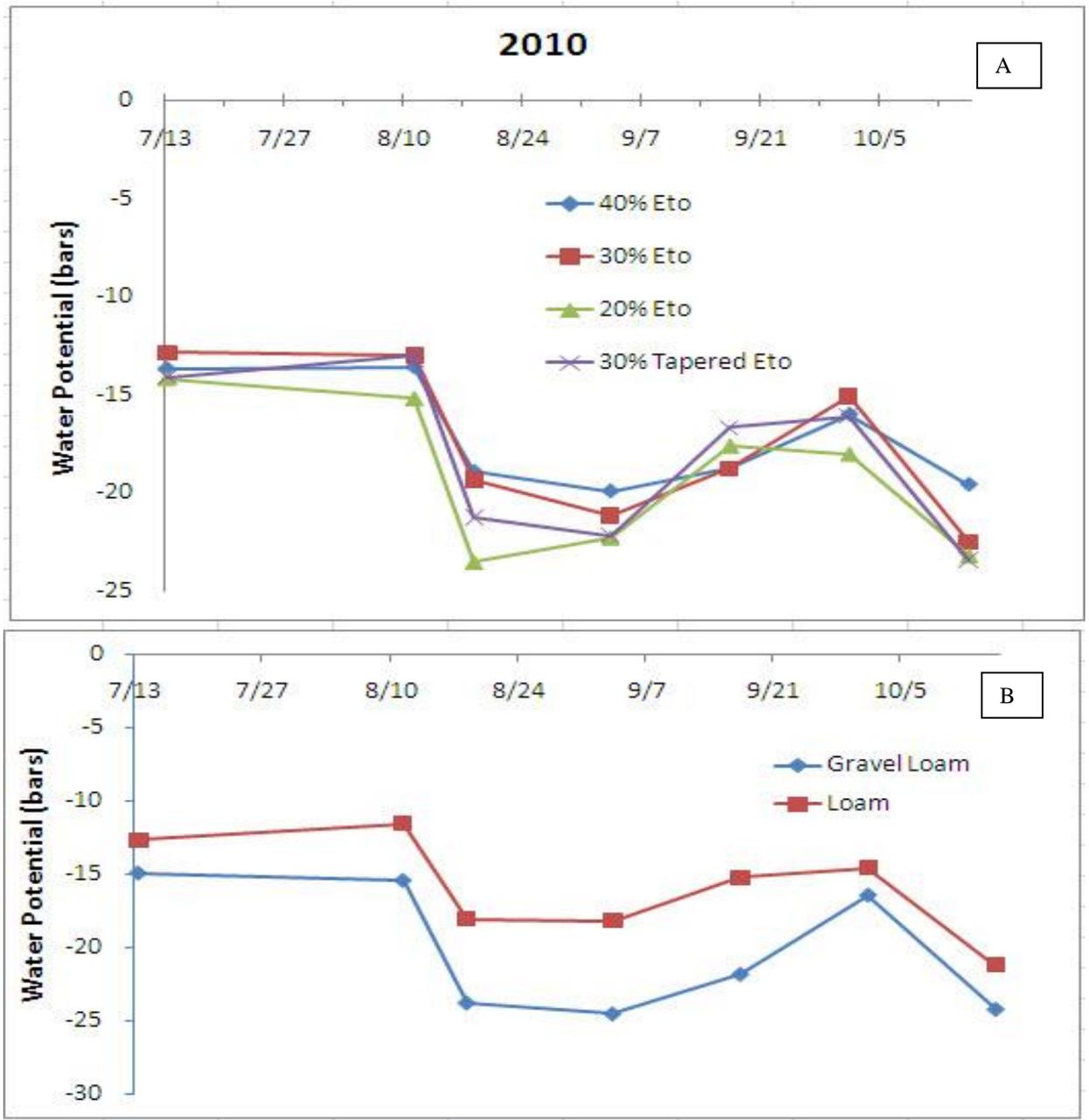


Figure 1. Plant water potential in RDI main plots (40% ETo, 30% ETo, 20% Eto, and tapered Eto) (A) and sub-plots (Gravel loam and Loam soils) (B) in 2010

New Insights on Water Management in Almonds

Blake Sanden, Irrigation & Agronomy Advisor, UC Cooperative Extension, Kern County
 1031 S. Mt. Vernon Ave., Bakersfield, CA 93307
 Phone (661) 868-6218, Fax (661) 868-6208, blsanden@ucdavis.edu

Patrick Brown, Irrigation & Agronomy Advisor, UC Cooperative Extension, Kern County
 One Shields Avenue, Department of Plant Sciences, 3019 Wickson Hall, Davis, CA 95616
 Phone (530) 752-0929 Fax (530) 752-4361, phbrown@ucdavis.edu

Rick Snyder, Biometeorology Specialist
 One Shields Avenue, Land, Air and Water Resources, 243 Hoagland Hall, Davis, CA 95616
 Phone (530) 752-4628, Fax: (530) 752-1793, rlsnyder@ucdavis.edu

Introduction

How much?! How often?! Those two questions are probably the most common questions asked not just in ag, but for all of humanity: “Dad, how much allowance do I get? How often do I have to take out the trash?” How much fertilizer and water does it take to make 5,000 lb/ac almond kernel yield?

Increasing almond yield: Figure 1 illustrates changes in almond acreage and yield in Kern County since 1980. The inset box identifies major changes in agronomic practice. The average yield for 2002-12 increased over 700 lb/ac compared to the previous 14 years. The large swings in the last 5 years are related to weather and juvenile orchard acreage counted as “bearing acres”. The Kern County average for 2010 was 2,620 lb/ac. One of Paramount Farming’s Kern County Westside divisions averaged 4,000 lb/ac for all Nonpareils for the 2011 harvest.

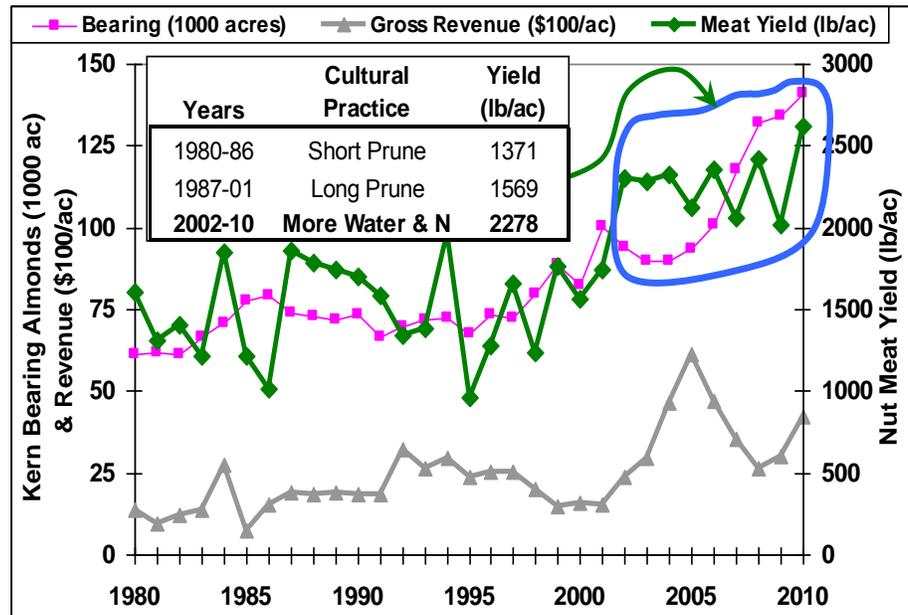


Fig. 1. Changes in bearing almond acreage, yield and gross revenue in Kern County from 1980-20010. (Source: Kern County Ag Commissioner) Comparison of 4 years of mature al-

mond canopy capture of sunlight to achieve maximum spur density and productivity, namely; high density plantings, “long pruning”, improved varieties, more timely and sufficient supply of nutrients, and, most significantly, a better understanding of truly non-stressed almond water use (evapotranspiration, ET). This paper will focus mostly on this last factor, but will also discuss some results on fertigation options and fertilizer type. This data has been derived from statewide and Kern County field trials from 2008 through 2011.

Estimating Crop Water Use (ET) Using Crop Coefficients (Kc)

One of the most common approaches to estimating production irrigation demand is still to assume a “normal year” irrigation schedule, usually based on experience and what your neighbors do, that might call for an irrigation every 4 to 14 days depending on the irrigation system and crop. A much more accurate preliminary estimate of actual crop ET (not just irrigation events) can be made by using published crop coefficients (Kc) and local estimates of potential evapotranspiration, ETo. Seminal international extension manuals promoting this method in production agriculture go back to the 1970’s (Crop Water Requirements, Doorenbos and Pruitt, 1977 and Yield Response to Water, Doorenbos and Kassam, 1979).

The general theory is that the Kc value represents the ratio of actual **non-stressed** crop water use compared to “reference crop” water use (like a well watered pasture) for that climate for a given stage of the crop growth. The initial theory also assumed that these seasonal Kc values, particularly for permanent crops, is constant regardless of where the crop is grown – hard-wired into the genetics of the species and any increase or decrease in the actual crop ET was climatically driven (i.e. it’s hotter and drier in Bakersfield than in Stockton). The most accurate Kc values are developed from crops planted in large weighing lysimeters where irrigation and subsequent water extraction by the crop is actually weighed. Other field and meteorological energy balance techniques have also been developed to estimate ET in actual field settings. The first California specific extension publications listing our major commodities started coming out in the 1980’s (Pruitt, 1987 and Snyder, 1989.) A detailed explanation of how to calculate crop ET using Kc values and ETo is described in these publications.

Kc values may be listed by crop stage of development, or more conveniently as a weekly or bi-weekly average. This last format is most convenient for growers as they can simply multiply the Kc by the local ETo (available on-line from the California Irrigation Management Information Service, CIMIS) to get an estimated or “normal year” crop water use for that week.

The right Kc values? Of course this calculation assumes that the crop was at full vigor and canopy size and not stressed when ET was measured and the Kc calculated for that period. Unfortunately, many of the early Kc estimates for permanent crops were made in flood irrigated orchards and vineyards where this was not the case. This is most likely the case with the original Kc values for deciduous crops (including almonds) published by Pruitt (1987) and Snyder (1989). The peak Kc value for almonds was assumed to be 0.95 for orchard with no cover crop. For a 57.9 inch CIMIS “normal year” southern San Joaquin Valley ETo (Jones, 1999) the yearly calculated almond ET with no cover crop equals 42.3 inches. This number was assumed to be the 100% non-stressed ET for numerous almond trials conducted from the late 1980’s to early 2000’s, even though there was often signs of stress in these “100% ET” treatments.

Production and extension field observations: At the same time a number growers, managers, consultants and some extension personnel in California and Australia were paying close attention to the trees and rootzone soil moisture reserves. Improved technology such as inexpensive loggers, capacitance/TDR probes, electrical resistance blocks and recording tensiometers for the first time gave us a 24 hour a day picture of water movement in the soil. This information, often showing declining soil moisture reserves, coupled with an improved understanding of tree stem water potential (SWP) stress thresholds convinced much of the almond industry that the old Kc/ET estimates were too low and limiting yield. After nearly 15 years of production experience and irrigation monitoring/scheduling extension demonstrations in more than 50 almond

orchards (Sanden, 2006) I upset a number of my UC extension colleagues by publishing my own set of almond Kc values starting in 2002, which peaked out at 1.08, for a yearly ET of 52.3 inches, a 23.6% increase over the old ET estimate. These values are listed in Table 1 below.

Table 1. "Normal Year" almond ET for different ages of trees irrigated with microsprinklers.

| CIMIS ET Estimates Using Shafter "Historic" ETo | | | | | | | | |
|--|-----------------------------------|--------------------------------------|---|-----------------------|-----------------------|-----------------------|---------------|--|
| Week | Normal Year Grass Eto (in) | Mature Crop Coef-ficient (Kc) | Almond ET -- Some Cover Crop, Microsprinkler (S. San Joaquin Valley Shafter, CA) | | | | | |
| | | | 1st Leaf @ 40% | 2nd Leaf @ 55% | 3rd Leaf @ 75% | 4th Leaf @ 90% | Mature | |
| 1/6 | 0.21 | 0.40 | 0.03 | 0.05 | 0.06 | 0.08 | 0.09 | |
| 1/13 | 0.28 | 0.40 | 0.03 | 0.06 | 0.08 | 0.10 | 0.11 | |
| 1/20 | 0.30 | 0.40 | 0.04 | 0.07 | 0.09 | 0.11 | 0.12 | |
| 1/27 | 0.36 | 0.40 | 0.04 | 0.08 | 0.11 | 0.13 | 0.14 | |
| 2/3 | 0.42 | 0.40 | 0.05 | 0.09 | 0.13 | 0.15 | 0.17 | |
| 2/10 | 0.47 | 0.40 | 0.06 | 0.10 | 0.14 | 0.17 | 0.19 | |
| 2/17 | 0.54 | 0.40 | 0.06 | 0.12 | 0.16 | 0.19 | 0.22 | |
| 2/24 | 0.61 | 0.40 | 0.07 | 0.13 | 0.18 | 0.22 | 0.24 | |
| 3/3 | 0.69 | 0.42 | 0.09 | 0.16 | 0.22 | 0.26 | 0.29 | |
| 3/10 | 0.79 | 0.61 | 0.14 | 0.27 | 0.36 | 0.43 | 0.48 | |
| 3/17 | 0.89 | 0.64 | 0.17 | 0.31 | 0.43 | 0.51 | 0.57 | |
| 3/24 | 0.98 | 0.67 | 0.20 | 0.36 | 0.49 | 0.59 | 0.65 | |
| 3/31 | 1.09 | 0.72 | 0.23 | 0.43 | 0.59 | 0.70 | 0.78 | |
| 4/7 | 1.19 | 0.74 | 0.26 | 0.48 | 0.66 | 0.79 | 0.88 | |
| 4/14 | 1.32 | 0.75 | 0.30 | 0.55 | 0.74 | 0.89 | 0.99 | |
| 4/21 | 1.41 | 0.81 | 0.34 | 0.63 | 0.85 | 1.03 | 1.14 | |
| 4/28 | 1.49 | 0.83 | 0.37 | 0.68 | 0.93 | 1.12 | 1.24 | |
| 5/5 | 1.59 | 0.86 | 0.41 | 0.75 | 1.03 | 1.23 | 1.37 | |
| 5/12 | 1.66 | 0.90 | 0.45 | 0.83 | 1.13 | 1.35 | 1.50 | |
| 5/19 | 1.73 | 0.94 | 0.49 | 0.89 | 1.22 | 1.46 | 1.63 | |
| 5/26 | 1.78 | 0.96 | 0.51 | 0.94 | 1.29 | 1.54 | 1.72 | |
| 6/2 | 1.85 | 0.98 | 0.54 | 0.99 | 1.35 | 1.62 | 1.80 | |
| 6/9 | 1.86 | 0.99 | 0.55 | 1.01 | 1.38 | 1.65 | 1.83 | |
| 6/16 | 1.90 | 1.02 | 0.58 | 1.06 | 1.45 | 1.74 | 1.93 | |
| 6/23 | 1.93 | 1.05 | 0.61 | 1.11 | 1.52 | 1.82 | 2.03 | |
| 6/30 | 1.93 | 1.06 | 0.62 | 1.13 | 1.54 | 1.85 | 2.05 | |
| 7/7 | 1.93 | 1.08 | 0.62 | 1.14 | 1.56 | 1.87 | 2.07 | |
| 7/14 | 1.93 | 1.08 | 0.62 | 1.14 | 1.56 | 1.87 | 2.07 | |
| 7/21 | 1.86 | 1.08 | 0.60 | 1.10 | 1.50 | 1.80 | 2.00 | |
| 7/28 | 1.86 | 1.07 | 0.60 | 1.10 | 1.50 | 1.79 | 1.99 | |
| 8/4 | 1.78 | 1.07 | 0.57 | 1.05 | 1.44 | 1.72 | 1.91 | |
| 8/11 | 1.75 | 1.08 | 0.57 | 1.04 | 1.42 | 1.70 | 1.89 | |
| 8/18 | 1.69 | 1.08 | 0.55 | 1.00 | 1.36 | 1.64 | 1.82 | |
| 8/25 | 1.62 | 1.07 | 0.52 | 0.96 | 1.30 | 1.57 | 1.74 | |
| 9/1 | 1.55 | 1.07 | 0.50 | 0.91 | 1.24 | 1.49 | 1.66 | |
| 9/8 | 1.47 | 1.06 | 0.47 | 0.85 | 1.17 | 1.40 | 1.55 | |
| 9/15 | 1.40 | 1.04 | 0.43 | 0.80 | 1.08 | 1.30 | 1.45 | |
| 9/22 | 1.31 | 1.02 | 0.40 | 0.73 | 1.00 | 1.19 | 1.33 | |
| 9/29 | 1.19 | 0.97 | 0.35 | 0.64 | 0.87 | 1.04 | 1.16 | |
| 10/6 | 1.10 | 0.95 | 0.31 | 0.57 | 0.78 | 0.94 | 1.04 | |
| 10/13 | 1.00 | 0.88 | 0.26 | 0.48 | 0.66 | 0.79 | 0.88 | |
| 10/20 | 0.90 | 0.88 | 0.24 | 0.43 | 0.59 | 0.71 | 0.79 | |
| 10/27 | 0.77 | 0.83 | 0.19 | 0.35 | 0.48 | 0.58 | 0.64 | |
| 11/3 | 0.67 | 0.78 | 0.16 | 0.29 | 0.39 | 0.47 | 0.53 | |
| 11/10 | 0.57 | 0.71 | 0.12 | 0.22 | 0.31 | 0.37 | 0.41 | |
| 11/17 | 0.48 | 0.68 | 0.10 | 0.18 | 0.25 | 0.30 | 0.33 | |
| 11/24 | 0.42 | 0.60 | 0.07 | 0.14 | 0.19 | 0.22 | 0.25 | |
| 12/1 | 0.36 | 0.50 | 0.05 | 0.10 | 0.13 | 0.16 | 0.18 | |
| 12/8 | 0.31 | 0.40 | 0.04 | 0.07 | 0.09 | 0.11 | 0.12 | |
| 12/15 | 0.29 | 0.40 | 0.03 | 0.06 | 0.09 | 0.10 | 0.11 | |
| 12/22 | 0.25 | 0.40 | 0.03 | 0.06 | 0.08 | 0.09 | 0.10 | |
| 12/29 | 0.21 | 0.40 | 0.03 | 0.05 | 0.06 | 0.08 | 0.09 | |
| Total | 57.90 | | 15.68 | 28.75 | 39.20 | 47.05 | 52.27 | |

Some progressive growers attained 4,000 lb/ac kernel yields in the early 2000's and most of the industry has responded with improved monitoring and increased precision and often quantity of fertigation and irrigation. Twenty years ago a yield of 2,500 lb/ac kernels was exceptional and you were considered to have a direct pipeline to the Almighty. This figure now barely pays the bills and 5,000 lb/ac is the new target. Unfortunately, we also see significant increases in disease in these well-watered and fertilized orchards. Increased hull-rot, some times phytophthora and syndromes such as "lower-limb dieback" have become increasing problems and threaten to shorten the life of the orchard.

Scientific Validation of a New Set of Almond Crop Coefficients

Field observation is one thing, but scientific validation is another. Starting in 2008, a statewide collaborative effort lead by Rick Snyder to validate new almond crop coefficients provided for the installation of sophisticated meteorological instruments to measure heat flux/ET in four fields from the southern San Joaquin Valley in Kern County to Butte County in the northern Central Valley. The

results for four years in Kern County are re-reported here. Figure 2 shows the weekly Kc values calculated from the measured orchard ET as determined by the Eddy Covariance technique used for all four orchards. Cumulative ET for each seasonal measurement period ranged from 49.1 to 61.5 inches. A combination of neutron probe and capacitance (PureSense) soil water content readings and weekly tree stress using the pressure bomb to measure SWP (maintain at -8 to -11 bars) were used to determine irrigation schedules so as to minimize stress. Significant hull rot problems began in this orchard in 2009 and some regulated deficit irrigation (RDI) at hull split was practiced in 2010 and 2011 to try and reduce infections; hence the reduced ET for 2010 and 2011. There are also reduced N fertilizer rate treatments in this block where the lower N rate did show less disease. Despite the irrigation deficit for both years hull rot still caused significant death in fruiting spurs in the lower canopy in the normal to high rate N treatments.

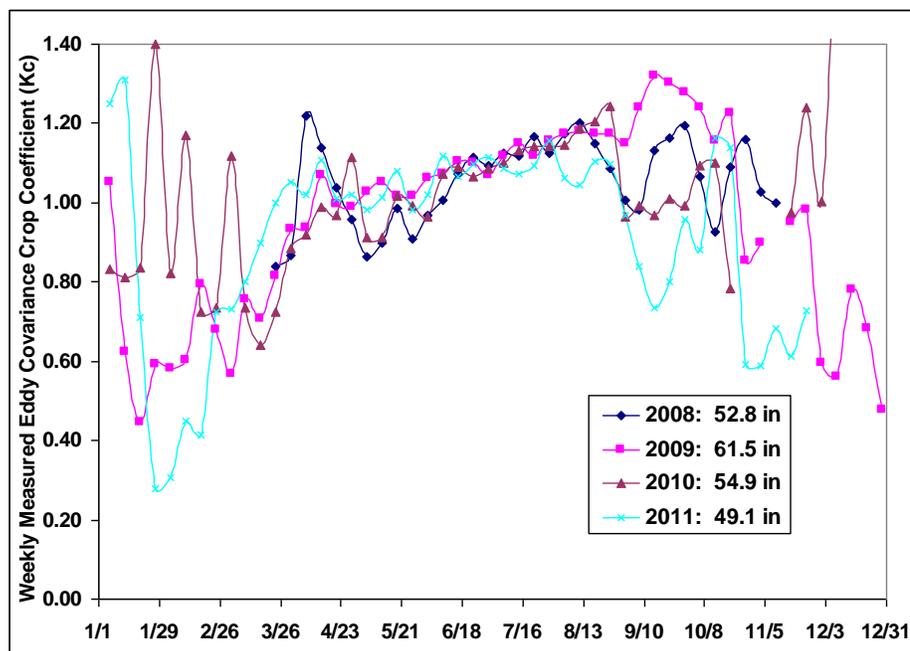


Fig. 2. Comparison of 4 years of mature almond crop coefficients (Kc) generated from Eddy Covariance heat flux estimates of crop ET divided by the modified Penman ET_o from the Belridge CIMIS station #146, 1.5 miles due west of orchard. (2008 ET measured 3/19 to 11/11. 2009 and 2010 are full year. 2011 is 1/1 to 11/22)

Figure 2 shows the erratic nature of measured Kc values in the spring and fall months from one year to the next. Total ET for these periods is much lower than in the summer and

prone to much greater variability from one year to the next. Summer “normal year” ET is much more predictable for most of California’s great Central Valley as seen in Figure 2 by the uniformity of Kc values from June to September, reaching a peak Kc of 1.15 before the stress of harvest cutoff prior to shaking reduces ET. The other sites in this state-wide study found similar Kc values. The three sets of almond Kc curves (on a 15 day basis over the season), Pruitt (1987), Sanden (2006) and the combined average for the last four years of this Kern County trial, are shown in Figure 3.

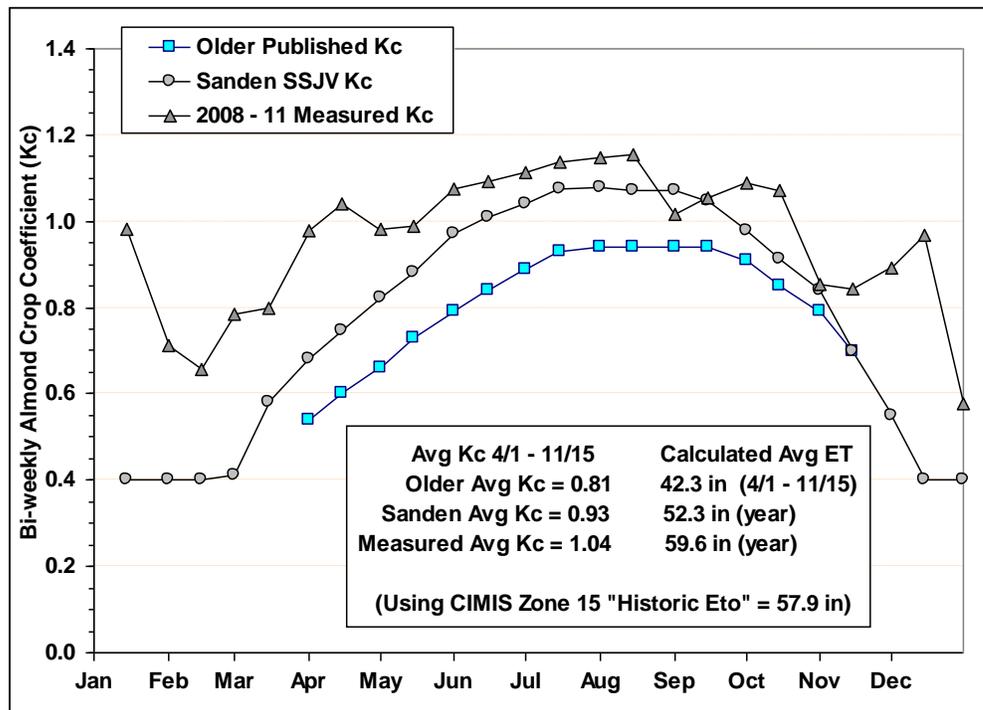


Fig. 3. Comparison of 3 Kc curves for mature almonds in the Central Valley irrigated without a cover crop.

Conclusion

This is not a recommendation to apply 60 inches

of water to almonds. Due to soil type and irrigation pressure differences in this orchard we have measured individual tree ET (using soil moisture depletion and chloride balances) that ranges from 49 to 62 inches. Figure 4 shows the individual yields from those trees and that there is no yield advantage above 50 to 52 inches of tree ET as long as sufficient winter leaching of salts is practiced.

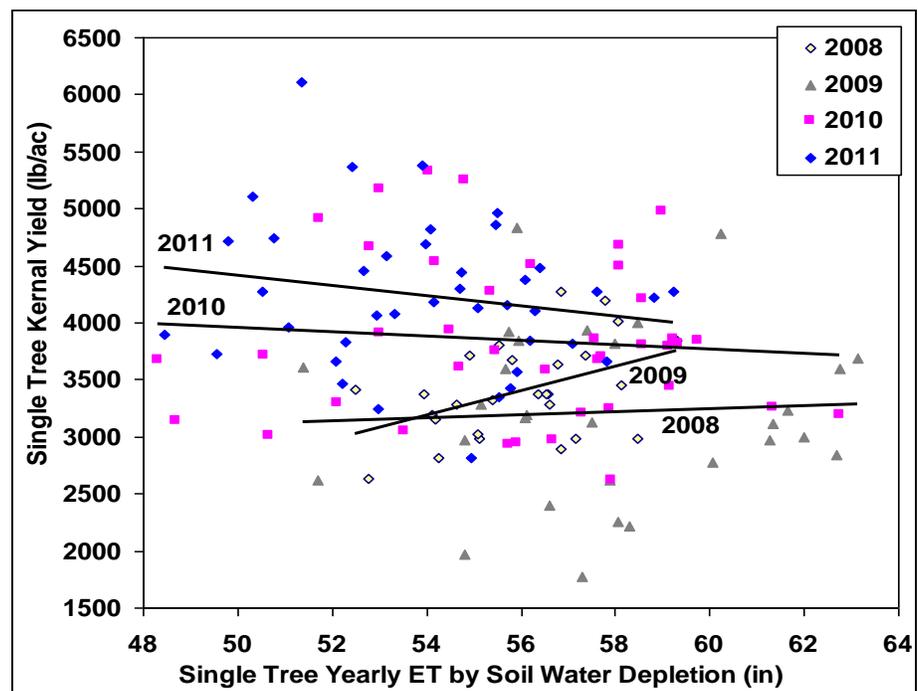


Fig. 4. Yield variation as a function of tree specific ET estimated by weekly measurements of applied water and soil water content change.

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Using EM and VERIS Technology to Assess Land Suitability for Orchard and Vineyard Development

Allan Fulton, Farm Advisor, University of California Cooperative Extension, Tehama, Glenn, Colusa, and Shasta Counties, 1754 Walnut Street, Red Bluff, CA 96080
Phone: (530)-527-3101, Fax: (530)-527-0917, Email: aefulton@ucdavis.edu

Larry Schwankl, Irrigation Specialist, University of California Cooperative Extension, Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648
Phone: (559) 646-6569, Email: schwankl@uckac.edu

Kris Lynn, GIS Academic Coordinator, University of California Cooperative Extension, Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648
Phone: (559) 646-6592, Email: krislynn@uckac.edu

Bruce Lampinen, Integrated Orchard Management Walnut and Almond Specialist, University of California Cooperative Extension, Department of Plant Sciences, One Shields Avenue, 1210 Plant and Environmental Sciences Bldg, Davis, CA 95616-8780
Phone: (530) 752-2588, Email: bdlampinen@ucdavis.edu

John Edstrom, Emeritus Farm Advisor, University of California Cooperative Extension, Colusa County, PO Box 180, 100 Sunrise Boulevard, Suite E, Colusa, CA 95932
Phone: (530) 458-0570, Email: jpedstrom@ucdavis.edu

Terry Prichard, Emeritus Irrigation Specialist, University of California Cooperative Extension, 2101 East Earhart Avenue, Suite 200, Stockton, CA 95206
Phone: (209) 953-6100, Email: tlprichard@ucdavis.edu

Summary

Orchard and vineyard producers conduct preplant site evaluations to help prevent planting permanent tree and vine crops on lands where the crop will not perform to its highest potential or attain its full life expectancy. Physical soil characteristics within specific soil profiles and spatially throughout an orchard influence decisions on land preparation, irrigation system selection, horticultural choices, and nutrient management. Producers depend on soil surveys to help them understand the soil characteristics of the land and may be interested in technology that provides additional information.

Electromagnetic induction (EM38) and four-probe soil resistance sensors (VERIS) are being used in combination with global positioning systems to map spatial variability of soils using apparent soil electrical conductivity (ECa). The hypothesis evaluated in this study is whether rapid, in situ, and relatively low-cost methods of measuring ECa (EM38 and VERIS) can effectively identify and map physical soil variability in non-saline soils. The supposition is that in non-saline soils, ECa levels will relate well to soil texture and water-holding capacity and can be used to map physical soil variability. In turn, the information can be used to guide decisions on preplant tillage, irrigation system design, water and nutritional management, and other horticultural considerations.

Two sites in the Sacramento Valley were mapped each with EM38 and VERIS methods. Site-specific management zones were identified by each provider on ECa maps for each site, and then soil samples were collected and analyzed by University of California researchers to verify these zones.

Results showed that on non-saline soils, ECa measured with both EM38 and VERIS correlate with physical soil properties such as gravel, sand, silt, and clay content but the relationship between conductivity and these physical soil properties varied from moderately strong to weak. The strength of the correlation may be affected by several factors including how dominant soil texture is on conductivity relative to other soil properties and on methods of equipment operation, data analysis and interpretation. Overall, the commercial providers of ECa surveys in this study delivered reasonable levels of accuracy that were consistent with results reported in previous studies. At one site, an ECa map developed with VERIS provided more detail on physical soil variability to supplement published soil surveys and aided in the planning and development of a walnut orchard. At a second site, almond yield appeared to correlate well with distinctly different soil zones identified with EM38 mapping.

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American Society of Agronomy

California Chapter

Session IV
Pests n' Pollinators

Session Chairs:

Carol Frate

Brad Hanson

Rodrigo Krugner

Overview of Current Quarantines and Management of Citrus Pests in California

Raymond K. Yokomi, Research Plant Pathologist

USDA, Agricultural Research Service
9611 S. Riverbend Ave. Parlier, CA 93648
559-596-2990; Ray.yokomi@ars.usda.gov

Introduction

California's diverse agriculture, favorable climate, geography and demographics provide many opportunities for establishment and spread of new invasive pests. Exotic pest exclusion and management are keys to minimize risk and maintain the State's agriculture free from new pests or limit their spread if introduced. Since my expertise is citrus, I will use citrus pests as examples to describe general approaches to prevent or control quarantine pests which should provide relevant information for any agronomic crop.

Citrus is an ancient commodity, however, modern citriculture is based on graft propagation on various rootstocks. There are at least 15 known graft-transmissible disease agents; ~7 are vector-borne (Roistacher 1991). Citrus foliage remains green throughout the year and provides a year-round food source for insect and mite pests and pathogens. Arthropod pests cause both direct feeding damage including fruit flies as well as indirect damage by transmitting disease agents. Control of these pests is achieved through quarantines, regulations, surveys and management.

Horticulture

Citrus originated in tropical and subtropical Asia and were grown as seedlings. Since very few citrus pathogens are seed-borne, they were largely pathogen-free. In the early 19th century, fruits and containerized plants were moved long distances by ship and citrus was disseminated intercontinentally by explorers and colonizers. *Phytophthora*, a soil-borne fungus, and *Citrus tristeza virus* (CTV), an aphid-borne virus, hitch-hiked to new regions as infections or infestations in these propagations (Moreno et al. 2008). Spread of these pathogens in new regions resulted in catastrophic disease and whole-field tree loss and spurred development and use of tolerant and resistant rootstocks. Judicious selection of rootstock (e.g. disease-resistant or tolerant, drought- or freeze-tolerant, salt (calcareous) tolerant, etc.) lead to expansion of the geographic range of the crop in temperate and arid regions. Drip and micro-jet irrigation allowed further regional expansion. Unwitting transport and propagation of pathogen-infected plants and budwood spread the disease agents to new regions.

Insect and mite pests

Common pests of citrus include an assortment of hemipterous insects such as armored and unarmored scales, whiteflies, mealybugs, aphids, and also thrips and weevils. Mites including rust, bud and spider mites have become common pests in cultivated citrus. These pests are controlled by integrated pest management (IPM) combining biological control with judicious pesticide use (Kobbe et al. 1991). The UC IPM Guidelines for Citrus web site (<http://ucipm.ucdavis.edu/PMG/selectnewpest.citrus.html>) provides a list of pesticides recommended to control these pests. Citrus fruit are hosts for Tephridid fruit flies.

Diseases

Graft-transmissible diseases of citrus are caused by diverse pathogens which are viral, viroid and bacterial in nature. Viroids are easily transmitted mechanically but have no known vectors. Important vectored bacterial diseases in California include: stubborn and phytoplasmas (e.g. beet leafhopper-transmitted virescence agent). Vector-transmissible bacterial disease agents not present in California include those causing Citrus Variegated Chlorosis (CVC) and those associated with Huanglongbing (HLB) or Greening. Known vectored viral pathogens that occur in California include those causing Tristeza and Vein Enation (woody gall); not present in the State are Citrus Chlorotic Dwarf and Leprosis (Timmer et al. 2000, Wallace 1978,). However, insect vectors for all these pathogens are present in California. Non-vectored disease agents infecting citrus include exocortis and cachexia. Some old-line citrus (non-nucellar) plantings still exist in California, hence, a few trees with Psorosis, Cristacortis, and Impietratura can be found. Some recent data suggest a psorosis strain can be transmitted by an *Opidium* fungus through flood irrigation (Figueroa et al. 2010). Seed-borne viruses include Tatterleaf-Citrange Stunt and Citrus Leaf Blotch Virus or Dweet Mottle. Other importance citrus pathogens include citrus canker, caused by a bacteria, and the fungal diseases of citrus black spot, citrus scab, septoria, and Mal Secco (Klotz 1978, Timmer et al. 2000). Control strategies will be discussed in the next section.

Certification program

California has been the worldwide leader in discovery and diagnosis of graft-transmissible citrus pathogens and production of pathogen-free citrus. In 1956, the University of California, Riverside, established a program which became known as the Citrus Clonal Protection Program (CCPP) under the management of the Dept. of Plant Pathology and Microbiology. The CCPP works cooperatively with CDFA, APHIS, California Citrus Nursery Board, National Clonal Germplasm Repository for Citrus and Dates and the citrus industry. The mission of the CCPP is to provide a safe mechanism for the introduction of citrus varieties from any citrus-growing area of the world and variety improvement (Vidalakis et al. 2010a). This program includes disease diagnosis, pathogen elimination followed by maintenance and distribution of healthy, true to type primary citrus propagative material of important fruit and rootstock varieties for the California citrus industry. The primary method of pathogen diagnosis is indexing in indicator plants which require specific greenhouse growing conditions and from 6 to 12 months to complete. With advances in molecular biology, some pathogens are now detected by serology using enzyme-linked immunoassay (ELISA) and tissue blot immunoassays, culturing or molecularly by sequential polyacrylamide gel electrophoresis (sPAGE for viroids), and polymerase chain reaction (PCR) (Vidalakis et al. 2010a).

Quarantines

Citrus quarantine in California is a cooperative program involving Federal, State and County Departments of Agriculture and the CCPP (Vidalakis et al. 2010a). Federal regulations are established and maintained by APHIS-Plant Protection and Quarantine (PPQ) and CDFA. Importation of citrus and movement across international and state borders are allowed only by permit from APHIS-PPQ. Permits are granted upon request and justification to the CCPP. Growers and nurserymen must go through the CCPP to import proprietary material. All citrus germplasm imported to California enter through the UC Riverside CCPP quarantine facility at Rubidoux. Samples are tested for the pathogens mentioned in the previous disease section.

Pathogens detected are eliminated by shoot tip grafting and/or thermotherapy. These interventions are necessary on all imported citrus germplasm, therefore, resultant plants must be retested to insure pathogen-free status and then entered into a Variety Introduction (VI) index on indicator seedlings and laboratory tested with methods previously mentioned. Once the pathogen-free status is confirmed, the source selection is propagated on clean rootstocks and planted in the field to determine tree and fruit quality and production in California. Once the citrus plant is released from quarantine, it is moved to the Lindcove Foundation Block in Exeter for distribution to the industry and researchers. A summary of this program is provided by Vidalakis et al. (2010a).

Surveys (examples)

Border stations. Homeland Security through the Transportation Security Administration (TSA) operates the California-Mexico border stations as well as sea and airline ports of entry into California. These inspectors look for and confiscate banned plant and meat products. Suspect pests are sent to APHIS labs for identification by experts. CDFA operates 16 other border stations (e.g. Truckee, Topaz, Needles, Blyth, etc.) to monitor phytosanitary compliance of interstate regulated products in freight trucks and by tourists. Banned plant material are confiscated and destroyed; suspect pests are sent to CDFA experts for identification (Tye Hafner, Fresno Co. Ag Commissioner Office, personal communication).

Fruit flies. Exotic Tephritid fruit flies are periodically found in urban settings on citrus or other fruit trees and vegetables. Oriental, Mediterranean, Melon and Mexican fruit flies are monitored by CDFA inspectors in urban areas using various traps baited with pheromones or other attractants. If an infestation is found, the homeowner or resident is notified and requested to allow treatment of the pest with an accepted insecticide by CDFA (CDFA PHPPS PEB 2001). Follow up surveys are conducted over a reasonable period to time to insure eradication was achieved. Infestation of fruits flies has direct consequences with the export of California citrus to other citrus producing states or countries.

Glassy winged sharpshooter (GWSS). The GWSS was inadvertently introduced into southern California in the early 1990s as egg masses on ornamental or agricultural plant foliage. This xylem-feeding insect has a wide host range, great mobility and is important because it can vector *Xylella fastidiosa*, the causal agent of Pierce's disease of grape and leaf scorch diseases of oleander, almond and mulberry. GWSS populations are limited in the State by quarantines and monitored by yellow sticky traps in urban landscapes and commercial citrus groves. Adult populations in southern California and SE Kern Co. typically move to citrus groves to overwinter. An Area-Wide GWSS control program was developed to treat overwintering GWSS with imidacloprid in infested citrus acreage (Sisterson et al. 2008). In urban landscapes, plants with GWSS infestations are also treated with imidacloprid which is also registered for home and landscape use (Varela et al. 2007).

Light brown apple moth (LBAM). Citrus is among the hosts for this invasive pest. Pheromone traps are set out by CDFA and county agricultural commissioners and checked regularly by state biologists. As a class A-Pest, infestations are treated by the regulatory agency with various

insecticides in nurseries and host crops (Johnson et al. 2007). LBAM has quarantine consequences with export of California citrus to other citrus producing states or countries.

Asian citrus psyllid (ACP) and HLB. The Asian citrus psyllid became established in southern San Diego Co. in 2008. As of fall, 2011, it has spread widely in some urban areas based on positive yellow trap catches in San Diego, Imperial, Riverside, San Bernardino, Los Angeles, Orange, and Ventura Co. and these areas are now under ACP quarantine (CDFA Staff 2011). The ACP is the vector of the bacterial agent associated with HLB, “*Ca. Liberibacter asiaticus*” (Grafton-Cardwell et al. 2006). So far, HLB has not been found in California. In Florida, both the vector and the pathogen are present and HLB is devastating their citrus industry (National Research Council 2010, Polek et al. 2007). ACP surveys are conducted by yellow sticky traps hung on citrus trees. CDFA conducts trapping and follow up surveys in urban areas. Details of the urban trapping and treatment program are detailed in a report by CDFA Staff (2011). Trapping in commercial citrus groves is done by inspectors hired by the California Citrus Research Board (CRB) and the Citrus Pest and Disease Prevention Committee (CPDPC) through a grant to the CRB. In the event that an ACP population is found in commercial citrus, a response plan and treatment regime is already in place (Grafton-Cardwell et al. 2011). The CRB/CPDPC established a diagnostic laboratory in Riverside in 2009 which was recently named the Jerry Dimitman Laboratory. In 2011, this lab was certified by APHIS for diagnosis of HLB-associated bacteria (CPDPP 2011). All ACP trapped as well as citrus or citrus relatives with HLB-suspect symptoms are sent to the Riverside lab and tested for presence of HLB.

CTV. Detection and eradication of CTV in central California is conducted by the grower-funded Citrus Pest Detection Program (CPDP) (aka Central California Tristeza Eradication Agency (CCTEA)), Tulare, CA. The CPDP surveys for CTV in ~20% of all citrus including dooryards in 5 Pest Control Districts in the San Joaquin Valley (Polek 2010). This region encompasses ~242,200 acres of citrus. Due to recent spread and increase in CTV reservoir trees, the CPDP adopted a new operational plan in 2010 to test for CTV strains and remove only trees infected with virulent strains of CTV which currently is at very low incidence (Barnier et al. 2010, Yokomi et al. 2011).

Septoria. Septoria is a fungal disease of citrus present at low incidence in central California but does not occur in Korea. South Korea is the second largest export market for California citrus. To keep this trade market open, the California industry maintains compliance with quarantine measures to prevent introduction of septoria to Korea. The Navel and Valencia Export to Korea (NAVEK) lab was created through a federal grant (USDA Foreign Agricultural Service Technical Assistance for Specialty Crops (TASC)) in 2005 and successfully developed efficient fruit sampling strategies and molecular-based pathogen detection based on PCR. NAVK also identifies and facilitates registration of new pre-and postharvest fungicides to manage the disease (Adaskaveg and Cranney 2011). The NAVK-developed work plan is now accepted by APHIS and the Korean Quarantine Service and is operational.

Citrus nursery inspection. Since 1962, California citrus nurseries have participated in a citrus budwood registration program which includes annual testing for CTV and a 5-year voluntary cycle of testing for psorosis, psorosis-like agents and citrus viroids by the CDFA and the CCPP. CTV testing is mandatory requirement of the CTV State Interior Quarantine§3407. In May

2010, a new regulation program (CDFA §3701-3701.8) was enacted due to heightened threats of invasive pests like ACP and HLB. New regulations now instituted are: i) Requirement for annual testing for HLB for registered citrus nurseries; ii) scion mother trees and seed source trees must originate from pathogen-free CCPP sources or those tested to be pathogen-free by the CCPP; iii) registered scion mother trees and seed source trees must be grown in a CDFA-approved insect-proof structures by January 1, 2012; iv) increase trees must be maintained in an approved insect-proof structures by 2013 and used for only 36 months before retesting is needed; v) requirement for annual CTV remains unchanged; iv). Testing frequencies for other pathogens were decreased from 5 to 3 years (Vidalakis et al. 2010b). These new regulations can be viewed at http://www.cdfa.ca.gov/phpps/regs_cns.html#cns.

Detection

An assortment of methods are used to monitor quarantine pests; most have been already mentioned in previous sections. Insect traps are based on attraction, whether by pheromones, olfaction (baits) or visual (color). Traps must be at strategic locations: at/near borders and pathways of border traffic; ports of entry; residential properties on susceptible hosts, grower fields along grove edges. Ground truth visual surveys are always included as traps are being serviced. Sweep nets, motorized or battery-powered suction devices (e.g. D-vac), beat nets, tap samples are additional tools needed to supplement traps and are essential in delimiting surveys. Pest collections are carefully examined by trained taxonomist or specialist with or affiliated with CDFA or APHIS.

Proper disease diagnosis also has critical requirements. Virus and viruslike pathogens are graft-inoculated in indicator plants and held for development of visual symptoms by the CCPP. Serology, especially ELISA, is a robust procedure and is used when good antiserum is available. Bacterial causal agents of stubborn, canker, CVC and fungal diseases are isolated and cultured on cell-free media. With molecular advances and knowledge of discerning genetic sequences to identify pathogens and insect pests, PCR have now become routine and accepted procedure for diagnosis of many regulatory pests. Diagnosis is typically performed by experts in APHIS, CDFA, CCPP or ARS and must follow strict guideline and include suitable controls.

Eradication

Eradication of quarantine pests is a desirable outcome but can be unrealistic or short-lived. It can be achieved if certain favorable circumstances prevail. These include, but are not limited to, factors of host range, biology, extent and pest distribution in the infested area, application logistics of chemical controls and availability of effective registered products, public and financial support, etc. Even with the best methods possible, the best result is often pest elimination or suppression in the infested area. In this case, it is critical that sufficient resources and logistics remain so that with upon pest recurrence, the control battle can quickly resume. Quarantine pests limit export markets or necessitate post-harvest treatment which can be expensive and decrease quality or shelf life of the commodity. A “systems approach” (Hansen and Lewis 2011) involving risk analysis, surveys during the growing season, proactive field treatments if needed, and certification of pest-free status, if accepted by the foreign trade partner, can allow export and acceptance of the commodity without postharvest treatment

Removal of citrus trees infected with a quarantine pathogen is effective as long as inoculum reservoirs and vectors are maintained at lowest level possible. Growers and inspectors must be aware that a latent period lasting months or years may occur in a newly infected plant before it becomes symptomatic or pathogen concentration to reach detectable levels. This is a significant complication because young plants are usually more susceptible to infection than older plants. Since a replant has a high risk of reinfection, a grower could be quite reluctant to pull a productive tree “sick” tree and replant with a new tree which will require 2-3 years before bearing an economic crop.

Management

Once a pest is established, biological control and integrated pest management plays vital roles in maintaining the pest at low levels. Eradication by classical biological control agents is untenable. Parasitoids are often host specific and cannot survive unless their host is present. Predators are often generalist feeders and have mobility to move to new sites when host availability is low. Despite these caveats, natural enemies are essential and must be protected in the urban and agricultural landscapes to help manage these established arthropod pests.

Summary

Challenges posed by invasive quarantine pests are immense and have immediate consequences on export and interstate markets, increase production costs, pesticides, and reduce yield and quality. Therefore, the best protection is exclusion of exotic pests. Quarantines to restrict movement of contaminated plants to uninfested intrastate areas are just as important as border stations to limit pest spread. This report utilized examples from citrus to describe the organization and coordination needed by the industry with federal, state and County Agricultural Commissioner agencies to safeguard crops and domestic and foreign markets. Growers must partner with other growers, regulatory agencies, private companies and researchers to develop the best means to detect, delimit and suppress exotic pests when they occur. Last but not least, outreach activities to inform the grower and general public about invasive pests is vital. The key points in this report include, but are not limited to, pathways of entry, biology, regulations, quarantines, surveys, detection, eradication, post-harvest treatment, enforcement and outreach.

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Commodity Export Treatment Requirements and Regulations

John Lloyd, Trade Specialist
USDA-APHIS
2202 Monterey Street
Suite 104
Fresno, CA 93721
(559)-233-3165 (office)

NOTES & QUESTIONS:

Postharvest Fumigation of Specialty Crops

Spencer S. Walse, USDA-ARS
San Joaquin Valley Agricultural Science Center
Parlier, CA 93648

Abstract

United States agricultural industries are facing, with increasing frequency, environmental and pest-related food safety requirements that are fundamentally difficult to balance. Failure to properly sanitize foodstuffs in trade and marketing channels can result in insect- and microbial-derived damage that limits economic profitability, curtails market access, and vectors plant, animal, and human illnesses. Despite a historic precedence of effectiveness, the use of chemicals, including fumigants, for disinfestation and disinfection of foodstuffs is under close regulatory supervision due to consumer consciousness regarding unintended health effects resulting from chemical residues. Regardless of personal viewpoints, or merit of scientific backing, advocacy and opposition to chemical treatment is expected to continue. This article describes experimental infrastructure and critical research elements of the Crop Protection and Quality Research Unit of the USDA-ARS-SJVASC that specifically address this contemporary dilemma, one that will only become more challenging and important as the role of the United States in feeding the world expands over the next decades. In particular, recent developments in postharvest chamber fumigations are presented, such as methyl bromide and alternative phytosanitary treatments for insect control, strategies to limit or reduce emission of fumigants to the atmosphere, and novel technologies for residue removal.

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. 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 1ft³ chambers, all of which are equipped with fans, pressure regulators, and centralized exhaust aeration systems (USDAb, 2009). In addition, there are three 9 ft³, two 133 ft³, and a 500 ft³ 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.

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Importance of the Honey Bee Pollination Industry and the Threats to Its Sustainability

Gordon I. Wardell, Apiculturist, Paramount Farming Company
33141 E. Lerdo Highway, Bakersfield, CA 93308
Phone (661)477-0256
Email GordonW@paramountfarming.com

Introduction

For three thousand years, since the time of the early Egyptians, man, bees and agriculture have evolved a mutualistic relationship that benefits all involved. The balance between the three parties is a precarious relationship, if one member falls out of balance all parties are impacted. As man selected pollinated plants that supported his nutrition, the bees were supported by the added plants to pollinate and the plants were in turn supported by the bees. In addition, the bees that prospered were those that could thrive in the provided habitats and in return for a safe healthy environment, man was rewarded with surplus honey from the bees. Other examples of this relationship are seen in the introduction of chlorinated hydrocarbon pesticides in the mid 1940s (Anderson and Atkins, 1968), and later, the arrival of Varroa mites in the United States in the 1980s (Sammataro et.al 2000). In both cases beekeepers and regulatory organizations had to work together to restore the balance to protect the bees and preserve pollination and honey production. Work being done today on Colony Collapse Disorder is yet another example of how man is working to restore the balance through active research, while at the same time growers are looking to possibly supplementing floral forage through diverse plantings in an effort to support the bees.

One third of everything we eat today is directly responsible to honey bee pollination. Rising costs of supplies and transportation, coupled with new bee diseases, honey bee pests and parasites are all putting this delicate balance at risk.

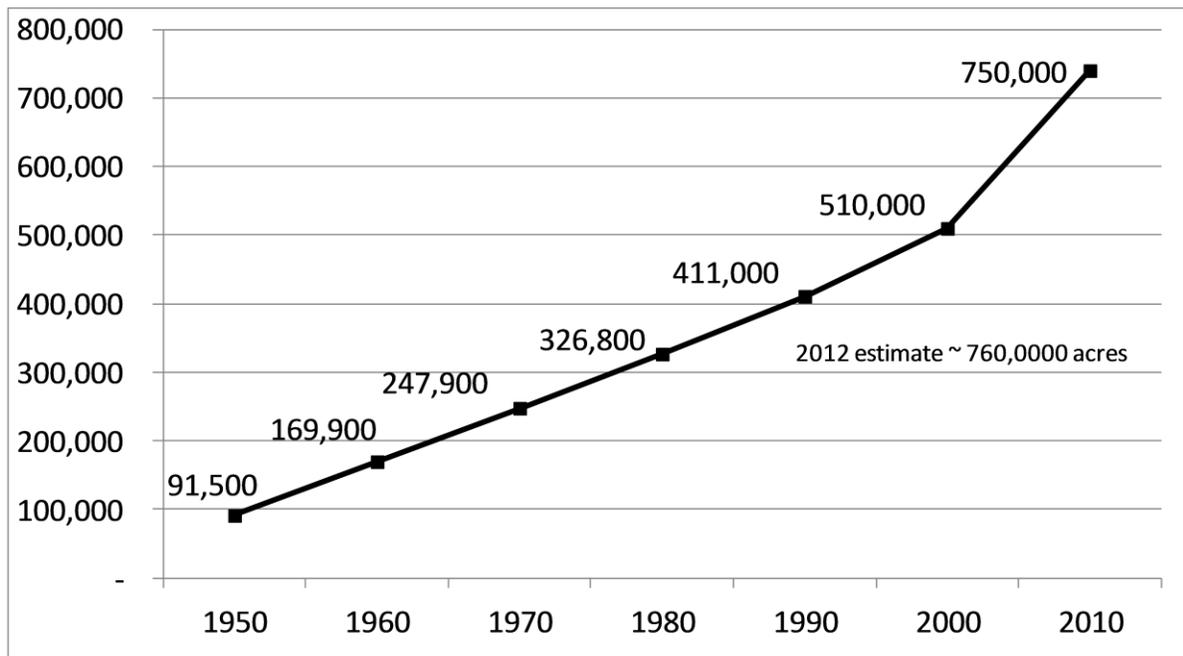
Intensive Agriculture and Crop Pollination

There are roughly 2.4 million commercial honey bee colonies in the United States that are responsible for an estimated 15 to 18 billion dollars worth of agricultural production. Crops from apples to zucchini depend on honey bee visits to set a crop. To affect well distributed pollination, colonies are usually distributed throughout the orchards and fields because of the sheer enormity of the acreages being pollinated. In the past, small farms were able to rely on feral bees and native pollinators to supply adequate pollination, but Varroa mites decimated feral honey bee populations and modern farming techniques along with pesticide applications have reduced native pollinators as well. Today, growers pay as close attention to pollination as they do fertilizers and water because without pollination there would be no crop.

As a single crop, almond pollination draws the greatest numbers of colonies on an annual basis to service its pollination needs. In 2012, an estimated 1.5 million honey bee colonies will pollinate 760,000 acres of California almonds, producing a crop with a value in excess of 3 billion dollars. To accomplish this Herculean feat, colonies will be trucked to California from all over the country, from Maine, Florida, Texas, the Dakotas and Washington State, all to provide bees for almond pollination because there simply aren't enough resident colonies California.

Until recently, pollination was a local matter. Local beekeepers, feral honey bee colonies and native pollinators were often enough to provide adequate pollination, but with the introduction of Varroa mites this balance changed. Feral colonies died out, many small beekeepers got out of the pollination business leaving growers without adequate pollination. So as demand rose, pollination fees rose as well. Around the same time, acreages of commercially pollinated crops began to skyrocket. Almonds led the growth with acreage doubling since 1990 (Figure 1. Almond Board of California, 2010). Adding to the demand, almond growers learned that strong colonies in their orchards gave a better chance of setting an optimum crop, so not just the demand for colonies grew but the demand for very strong colonies grew also. Today, the only way to produce large colonies that the growers are demanding is through intensive colony management and supplemental feeding.

Almond Bearing Acreage



SOURCE: USDA, NATIONAL AGRICULTURAL STATISTICS SERVICE, CALIFORNIA FIELD OFFICE (NASS/CFO)

Figure 1. California Almond Bearing Acreage over the last 50 Years

Costs of Preparing Honey Bee Colonies for Pollination

Preparing colonies for almond pollination is not a cheap process. It involves months of intense feeding and maintenance usually starting in August prior to bloom. It is not normal for a honey bee colony to contain eight to ten frames of bees and brood in early February and to push them to that size comes at a great cost both to the bees and the beekeeper. In 2009, Dr. Eric Mussen

(Extension Apiculturist, U C Davis) conducted a survey of successful California beekeepers to get an idea of what it takes to prepare a colony for early season pollination, including materials, labor and transportation. By Dr Mussen’s estimation an industry standard eight frame colony costs the beekeeper approximately \$190, and a ten frame colony pushes the cost to \$220 per hive. While pollination fees have tripled over the last 15 years (Figure 2.) the cost of preparing and moving the colonies is still below the added costs of preparing the hives for almond pollination. Across the board cost increases have hit the beekeepers hard, sugar to feed the bees has doubled in the last two years as have fuel costs and trucking costs to move the bees. Medication and protein feed for the bees have risen as well. With almond pollination fees between \$140 and \$155 for an eight frame colony, beekeepers have to plan for other sources of income from their bees to recuperate the costs of getting ready for almond pollination. Typically, beekeepers will take their bees to other crops for pollination following almond bloom or they will move to an area to make honey as an income source. Honey prices have been high lately because of increased demand and tighter controls on imported honey. This trend has helped beekeepers meet their added incurred costs. In addition, because the bees are going into almonds so strong, they come out of almonds even stronger, and rapidly expanding colonies need to be split to prevent swarming. These divides or “splits” can be a source of income for the beekeeper as well. There is a great demand for bees now on a year round basis.

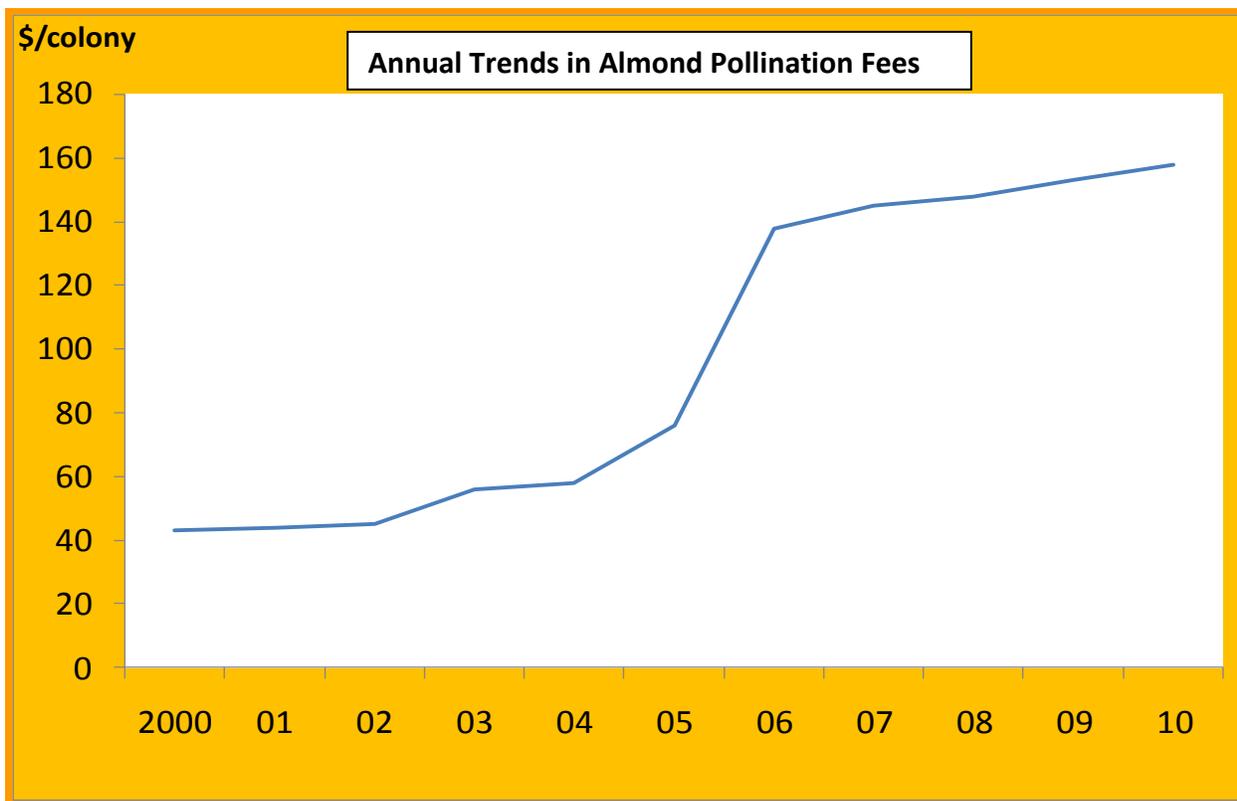


Figure 2. Almond Pollination Fees, courtesy of the Almond Board of California

Honey Bee Health

Colony availability has certainly been a factor in the dramatic rise in pollination fees. Increased demand and decreased availability of strong colonies has pushed the market to all time highs. Since 2005 beekeepers have been experiencing average losses near 35% of their colonies. New parasites, new pathogens, new diseases, new stresses have all contributed to these losses. Whether it is called Colony Collapse Disorder, Nosema disease or Israeli Acute Paralysis Virus the result is the same, beekeepers who have never had more than 15% winter loss are experiencing 35% to 50% loss on a regular basis. While losses like these are nearly double what they were experiencing fifteen years ago, beekeepers are learning to manage their losses through frequent requeening, intensive disease management, equipment replacement and supplemental feeding. These efforts seem to help minimize the losses. However, these added management expenses further burden the beekeeper and challenge their ability to provide adequate colonies for pollination. To accommodate these challenges, many beekeepers have shifted their business model to only do pollination and using the surplus honey the bees make to produce more bees (colony splits), this helps them to recoup their colony losses but at a loss of income from the honey. To make up for the lost honey income, beekeepers take on more pollination contracts and thereby put even more stress on their colonies. Despite these losses and mounting challenges, commercial beekeepers continue to provide growers with colonies that meet their pollination needs and set ever growing production records.

Summary

The balance between bees, man and agriculture continues despite the problems consuming the bee industry today. America's crops continue to be pollinated unhindered, a record amount of honey is being produced, and beekeepers continue to replace colonies lost to CC D and other maladies. As almond acreage in California continues to grow, the challenge will be to find adequate numbers of strong bee colonies to pollinate the crop, but if we have learned anything from the past 3000 year relationship with honey bees, we can feel certain that market forces, the determination of man and the resilience of the honey bees will persevere.

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Pesticide Risk Assessment for Honey Bees A California Perspective

Rich Bireley, Senior Environmental Research Scientist
Department of Pesticide Regulation
Pesticide Regulation Branch
E-mail: rbireley@cdpr.ca.gov

In the United States, the honey bee (*Apis mellifera*) is the surrogate for many other non-target insects and insect pollinators. Honey bees are a challenging organism to study. Typically toxicity testing and risk assessment focus on effects to the individual organism, but in the case of honey bees, the colony is the organism. In a large healthy hive, hundreds of foragers die daily and the death of one is of little importance. As a result, U.S. EPA currently has a tiered testing approach. Tier 1 testing includes an acute contact test with young worker bees. Compounds with an $LD_{50} < 2 \mu\text{g a.i./bee}$ are considered highly toxic to bees and warrant further testing. Tier 2 testing currently consists of a foliar residue toxicity test. The endpoint of this test is a value indicating how long foliar plant residues are toxic to bees under laboratory conditions. Tier 3 testing includes either semi-field or field testing; however, standardized protocols for Tier 3 testing have not yet been established. With the introduction of new plant protection products, changes in agricultural practices, and advances in the science of honey bee biology, the ability to characterize potential risks to insect pollinators has become inadequate. In January 2011, a SETAC Pellston Workshop was held to assess and advance the state of the science on pesticide risk assessment for pollinators. The generic problem formulation for pesticide risk to pollinators includes two application strategies, foliar and application of systemic pesticides to seeds or soil. The new risk assessment paradigm is based on exposure estimates and a tiered toxicity testing system consisting of the previous tests plus a Tier 1 larval and Tier 2 10-day chronic adult test, as well as more structured protocols for semi-field and field testing. California has a unique approach to ecological risk assessment and risk management. Due to staffing levels, a full ecological risk assessment is not feasible. Non-target organism reviews incorporate the conclusions from U.S. EPA risk assessment documents when possible. In addition, these reviews contain a recommendation based on the submitted data (science based) regarding the registration of the pesticide. California is currently reevaluating four neonicotinoid insecticides. Finally, California has a novel interpretation of a pesticide label based on a specific pesticide label relating to residual toxicity of the active ingredient.

Development of wildflower mixes to promote native pollinators in agriculture.

Neal M. Williams, Assistant Professor
Kimiora Ward, Research Associate
Department of Entomology, University of California Davis
One Shields Ave., Davis CA, 95616
nmwilliams@ucdavis.edu

Recent surveys by USDA suggest that loss of honey bee colonies from CCD is stabilizing at approximately a third each winter (vanEngelsdorp et al. 2011), making management complicated and expensive. A sustainable future for California agriculture must involve a more integrated and diversified strategy that includes the use of wild and managed non-*Apis* pollinators in some contexts, augmentation of habitats to support native and managed bees and engagement of growers to implement strategies to promote diversified pollination. Such an **integrated crop pollination** strategy should serve to lessen the burden on already stressed populations of the honey bee and increase the reliability of pollination over time.

A key component of a more integrated crop pollination strategy involves use of wild native bee species. Pollination by wild species requires that abundant populations persist within agricultural landscapes. Declines of native bees have been linked to agricultural intensification and the resulting loss of foraging and nesting habitat, among other factors (Carvell et al. 2007; Williams et al. 2010). However, recent research has shown that this trend can be reversed and that native bees can contribute to crop pollination on farms where their habitat needs are met (Kremen et al. 2002; Winfree et al. 2007). One primary cause of low native bee abundance on farms is lack of sufficient floral resources.

Development of native plant mixes

Over the past three years we have begun a research program to develop and test mixes of native herbaceous flowering plants to support pollinator populations within commercial agriculture in California. This research simultaneously investigates establishment and floral productivity for different plant species and their attractiveness for wild bees, managed honey bees, and other insect pollinators. The project has three phases of which two are nearly completed and the third is underway.

Phase 1: Identification of annual and perennial wildflowers for candidate plant mixes.

We selected plant species and compiled mixes using four key criteria. 1. All plants must be native to California. 2. All species must be highly drought tolerant. 3. Within natural communities they must be preferred by bees as assessed by the abundance and diversity of bee species they draw. 4. As a mix, the species must provide continuous bloom throughout the growing season.

We assessed native status and drought tolerance from published literature and previous small scale planting trials in the northern Central Valley (J. Anderson, Hedgerow Farms Winters CA, unpublished data). Attractiveness and preference to bees were quantified based on preference indices (Johnson 1980) that calculate bees' rank use of plants compared to plants' rank relative abundance within naturally occurring communities. We calculated preference based on 8 samples collected throughout the growing season from 21 sites within the study region (Williams et al. 2011). Seasonal continuity of bloom was assessed based on the same sampling dataset and from collection records in Cal Flora. Based on our criteria we developed five mixes of plants, including two composed only of annuals, two composed only of perennials and one combining annual and perennial species (Table 1).

Phase 2: Test plant performance and ability to support native bee biodiversity in agricultural settings.

The five wildflower mixes were planted in 15 x 3m plots at each of three spatially independent study sites in Yolo County, CA. Plots were pretreated for weeds using solarization or glyphosate application, shaped to standard 5 ft beds, and broadcast seeded with the mixtures in November. Beds were covered after planting with floating row cover until early February. We measured establishment success of each plant species in all floral mixes in March and again in July using per-species stem counts and estimates of percent cover in standard quadrats. We assessed forage resources (pollen and nectar) available to pollinators in each mix based on flower density every three weeks from April-September.

During each floral sampling period, we also measured visitation rates and pollinator diversity to each plant species in each mix using timed observations and standard net collections. All insects in contact with the reproductive structures of flowers were identified to morpho-type and the plant species they were visiting was recorded. The following day, we collected floral visitors for identification to species.

Based on Phase 2 testing, we identified a wildflower mix containing plant species that established well within agricultural landscapes and attracted diverse and abundant pollinating insects throughout the growing season.

Phase 3: Enhancement of pollinators and pollination services to target crops.

The goal of this ongoing phase is to examine the functional performance of the preferred wildflower mix when grown at a scale suitable for commercial agriculture. In winter 2010/11 we planted the preferred mix at three sites adjacent to commercial watermelon fields. Plots were 300-600m x 5 m in size. At each site we quantified the establishment and attractiveness of each plant species in the preferred mix following the same methods as for Phase 2. In addition, we monitored the abundance and diversity of floral visitors to the target watermelon crop during bloom at different distances (1, 10, 40, 80 m into the field) from the wildflower strip. We took

the same measurements at the same distances from an un-enhanced border on a different watermelon field for the control. At the end of the season, we collected samples of watermelon from each distance and field type to quantify yield.

Wildflower mixes planted within intensive agricultural landscapes attracted significantly more pollinator individuals and species than un-enhanced margins. An average of 15.3 ± 1.7 native bee genera visited the preferred mix, compared to 8.3 ± 5.0 genera at control margins. Visitor abundance was also generally much greater at the wildflower mix versus unenhanced margin (Table 2).

Assessment of pollination differences between watermelon fields with and without wildflower enhancements is still underway. However, such wildflower plantings show great potential to support abundant and diverse pollinators within intensive agricultural landscapes. It would be particularly interesting to follow the performance and functioning of such plantings over time to better understand longer term benefits (Morandin et al. 2011).

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Table 1. Target species included in test seed mixes.

| Species | Common Name | Bloom Period | Color | Life history | Sown in Mixes |
|--------------------------------|----------------------|---------------------|-----------------|--------------|--------------------------|
| <i>Achilleamillefolium</i> | Yarrow | Summer | White | Perennial | PD |
| <i>Clarkia unguiculata</i> | Elegant Clarkia | Spring | Pink | Annual | AD |
| <i>Eschscholziacalifornica</i> | California poppy | Spring-summer | Orange | Perennial | PB, PD, Mix |
| <i>Grindelia camporum</i> | Valley gum plant | Summer-fall | Yellow | Perennial | PB, PD, Mix |
| <i>Helianthus bolanderi</i> | Bolander's sunflower | Summer | Yellow | Annual | AD, PD ¹ |
| <i>Hemizoniacongesta</i> | Hayfield tarweed | Summer-late summer | White | Annual | AD ² |
| <i>Lotus scoparius</i> | Deerweed | Summer | Yellow | Perennial | PB, PD, Mix ³ |
| <i>Lupinusdensiflorus</i> | Yellow lupine | Late spring-summer | Yellow | Annual | AD |
| <i>Lupinussucculentus</i> | Arroyo lupine | Spring | Purple | Annual | AB, AD, Mix |
| <i>Lupinusformosus</i> | Summer lupine | Late spring-summer | Purple | Perennial | PD |
| <i>Nemophilamenziesii</i> | Baby blue-eyes | Spring-early summer | Blue | Annual | AD |
| <i>Phaceliacalifornica</i> | California Phacelia | Early summer | Purple | Perennial | PB, PD, Mix |
| <i>Phaceliatanacetifolia</i> | Lacy Phacelia | Spring | Purple | Annual | AB, AD, Mix |
| <i>Rudbeckiahirta</i> | Black-eyed Susan | Summer | Yellow | Perennial | PD |
| <i>Trifoliumfucatum</i> | Bull clover | Late spring | Pink/White | Annual | AB, AD, Mix |
| <i>Trifoliumobtusiflorum</i> | Clammy clover | Late spring-summer | White | Annual | AD |
| <i>Trifoliumwildenovii</i> | Tomcat clover | Late spring | White to purple | Annual | AB, AD, Mix |
| <i>Trichostemalanceolatum</i> | Vinegar weed | Summer-late summer | Purple | Annual | AB, AD, Mix |

Table 2. Mean abundance per min \pm standard error among study sites (n = 3).

| Taxonomic group | Preferred mix | Control margin |
|-----------------|---------------|----------------|
| Native bee | 4.6 \pm 0.2 | 1.1 \pm 0.8 |
| Honeybee | 2.7 \pm 0.3 | 0.8 \pm 0.5 |
| Lepidoptera | 0.3 \pm 0.1 | 0.1 \pm 0.1 |
| Diptera | 1.0 \pm 0.3 | 0.6 \pm 0.5 |



American Society of Agronomy

California Chapter

Session V
Dairy Issues

Session Chairs:
Nathan Heeringa
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Nutrient Management on California Dairies: How to Help Your Clients

Deanne Meyer, Livestock Waste Management Specialist
Department of Animal Science, UC Davis
One Shields Avenue, Davis, CA 95616
dmeyer@ucdavis.edu

Patricia Price, Staff Research Associate
Department of Animal Science, UC Davis
One Shields Avenue, Davis, CA 95616
plprice@ucdavis.edu

Introduction

The California dairy industry employs close to 20,000 workers and has annual milk sales exceeding \$6.9 billion. Dairies are the mainstay of many rural economies. The California Dairy Quality Assurance Program works with its Partner organizations and regulatory agency staff to provide outreach to dairy operators and consultants.

Dairies are highly regulated. For example, in May, 2007, the General Order for Existing Milk Cow Dairies (GO) was adopted by the Central Valley Regional Water Quality Control Board (RB 5). The GO requires that all dairies in the Region be covered under the General Order or Individual Orders of Waste Discharge Requirements. A key component of these Orders is a comprehensive Monitoring and Reporting Program (MRP) defining required sampling media, frequency, and constituents. The MRP requires annual reporting of nutrient data collected from fresh water, liquid and solid manure, plant tissue, and soil. Sampling protocols and laboratory methods are defined elsewhere and must be approved by the Executive Officer. To date, the only approved sampling protocols are those initially provided by RB 5 or those written by UCCE Specialists and Advisors in collaboration with the California Dairy Quality Assurance Program (CDQAP) and approved by the Executive Officer. All approved protocols are identified on RB 5's website

http://www.waterboards.ca.gov/centralvalley/water_issues/dairies/general_order_guidance/sampling_analysis/index.shtml.

The first critical control point for obtaining useful data is collecting a representative sample. The CDQAP protocols were developed based on best professional experience and judgment. Each protocol presents a step by step procedure to obtain and preserve a representative sample for delivery to the analytical laboratory.

One challenge associated with reviewing nutrient data from solid and/or liquid manure from a single dairy is that there is insufficient sample size to provide a range of data from which to identify if the sample in question is 'reasonable' or an outlier. The objective herein was to review submitted data and identify areas for improvement in reporting and identifying outlier data. Improved sampling, preservation, and delivery methods may be helpful to reduce anomalies.

Materials and Methods

Annual Report records submitted to RB 5 by 170 dairy facilities covered under the GO between 2008 and 2010 were obtained and reviewed. Values submitted for solid and liquid manure analyses were analyzed to calculate the range and average concentrations for nutrients, identify potential thresholds beyond which data points could be considered to be outliers, and make suggestions for data entry quality assurance-quality control audit checks.

Estimated nutrient excretion (N, P, K, and total solids) for each category of animal present at dairies and knowledge of route and form of nutrients excreted from animals was used to identify expected nutrient EXCRETION ratios. Estimates of changes in these ratios based on dietary concentrations of nutrients, previous work with liquid manure waste streams and an understanding of manure management practices were also made.

Results and Discussion

Excretion of N, P, and K vary. As excreted by the ruminant, N is in the organic form (predominantly as undigested feed, microbial proteins, purines, pyrimidines, and urea). Very small amounts of N are excreted in the ammonium form. Urea is hydrolyzed to ammonium and CO₂ relatively quickly after excretion (usually within 24 hours). Urea-N may account for as much as 30% of the total N excreted by dairy animals, unless protein is overfed (the Urea-N increases both in quantity and as a percent of N excreted). Phosphorus is excreted as P₂O₄ in feces. Potassium is excreted in urine in the elemental form. Most of the N, P and K are soluble or occur in fine suspended solids (< 75 u) and remain in the liquid stream.

On most dairy facilities, the bulk of the manure (feces and urine) entering the liquid waste stream is from lactating cows. Estimates of N, P and K excretion from lactating animals fed within 113% of NRC Recommendations for crude protein intake (assuming 80 lbs of milk production) have a N:P:K of 5.8:1:1.3. This ratio will change based on dietary intake. Nitrogen excretion will also change based on dietary intake. N losses from manure can occur prior to entering the liquid waste stream, predominantly from ammonia volatilization.

In facilities where solids are used to bed freestalls the contribution of soluble nutrients to the liquid waste stream from the bedding will vary. Solids from corrals will have a full complement of soluble nutrients, but may have lost some N due to volatilization. Solids from mechanical separators will have a lower concentration of soluble nutrients (including N) compared to solids from corrals.

Review of submitted reports identified a number of limitations in data quality. For example, the report often uses units that differ from units reported by laboratories, resulting in unusually high or unusually low values. In addition, the form used to enter data requires a numerical value, therefore operators were forced to enter 0 when nutrient concentration was reported by the laboratory as below laboratory detectable limit. In some instances, ratios of nutrients reported within a single facility were far beyond what would be considered reasonable from a biological perspective.

After reviewing the submitted reports, it was often possible to identify whether a specific data point was reasonable or if it required further query. Based on our review, Table 1 provides suggested thresholds for identification of potential outliers based on reported data and a sound understanding of the biological conditions associated with manure excretion, collection, treatment, storage, and utilization.

| Table 1. Identification of thresholds for potential outliers of manure nutrient concentrations. | | |
|---|---------------|-----------------------------|
| Parameter | Solid manure | Liquid manure (as is basis) |
| Total Kjeldahl N | <0.5 or > 3 % | >2,000 ppm |
| Ammonium-N | n/a | >800 ppm |
| P | <0.2 or > 1% | >300 ppm |
| K | <0.75 or > 4% | >1500 ppm |
| EC (umhos/cm) | n/a | <500 or > 10,000 umhos/cm |
| TKN : Ammonium-N | n/a | <1.2 or >4 |
| TKN:P | < 1 or > 8 | <3 or >10 |
| TKN:K | <0.3 or >4 | < 0.4 or >3 |
| N – nitrogen; P – phosphorus; K – potassium; EC – electrical conductivity | | |

Summary

A number of recommendations can be made from this review of nutrient data. First, carefully check reporting units on laboratory reports and be sure the units match the Annual Report units. Second, be sure the basis of solid manure nutrient concentrations are consistently reported and entered in the Annual Report (i.e.: dry matter or ‘as is’). Third, check the application quantities of N, P, K and “salt” to ensure these values are not excessive. It may also be helpful to calculate or estimate the nutrient ratios listed in Table 1 in order to provide an additional level of data quality control.

Of course, it is critical to carefully review report data before actually submitting the Annual Report. Refer back to the actual laboratory reports if the concentrations of nutrients or nutrient ratios differ significantly from ‘reasonable’.

Helpful information:

http://www.waterboards.ca.gov/centralvalley/water_issues/dairies/index.shtml
http://www.waterboards.ca.gov/northcoast/water_issues/programs/dairies/
<http://www.cdqa.org/>

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Salinity and Dairies in the Central Valley: Long-term Prospects for Salt Management

Dennis W. Westcot, Consultant, Westcot Consulting
716 Valencia Ave, Davis, CA 95616-0153
Phone (530) 758-8373, westcotconsulting@sbcglobal.net

Jeanne E. Chilcott, Senior Environmental Scientist, Central Valley Regional Water Board
11020 Sun Center Drive, Suite 200, Rancho Cordova, CA 95670-6289
Phone: (916) 464-4788, jchilcott@waterboards.ca.gov

J.P. Cativela, Program Coordinator, Dairy Cares
915 "L" Street #C-438, Sacramento, CA 95814-3705
(916) 441-3318, dairycare@aol.com

Salinity is an increasingly critical water quality and water supply concern for the Central Valley and the Delta (Howitt et al., 2009). This problem however does not just affect the Central Valley, but all of California. Salinity impacts water used for drinking, farming, industry, and environmental and recreational uses in California. Salinity assessments are going on statewide and dairies must be a part of any salinity assessment.

Water Salinity

All water supplies contain some salt. Salts come in different chemical forms and from different sources, but all are difficult to remove once they are in the water. Sodium, chloride, magnesium, calcium, potassium, sulfate, carbonate, bicarbonate and nitrate all make up one word: salt. Salts are naturally occurring minerals and are integral to life on this planet. Water as rain and snow falls almost free of salt but begins picking up salts from minerals, rocks and soil that make up the earth's crust. As water flows to the sea it continues to pick up salt and increase in salinity concentration. The oceans or natural salt sinks such as the Great Salt Lake are nature's final resting place or disposal site for such salts. Part of the salinity increase results from plants and other forms of life that extract the water but leave behind the salts in the remaining water. This is part of the evaporation process as these salts move to the sea (Western Water, 2007).

When salt is discussed in relation to water, it is generally described in terms of total dissolved solids (TDS) which is the weight of salt in a given volume of water. TDS is commonly measured as milligrams of salt per liter of water (mg/L). For example, ocean water averages 35,000 mg/L while surface water supplies in California vary in concentration. Colorado River water averages about 700 mg/L, Sacramento River water about 100 mg/L, San Joaquin River water about 350 mg/L and State Project water about 250 mg/L as it is diverted from the Delta. Groundwater salinity levels throughout the state vary dramatically but groundwater with a concentration greater than 1,000 mg/L is considered undesirable for human and most irrigation uses (Western Water, 1999). Representative groundwater salinity in several Central Valley Counties is shown in Table 1 (DWR, 2003 and GAMA, 2007).

| County | Average TDS (mg/l) |
|---------------|---------------------------|
| Glenn | 325 |
| Sacramento | 230 |
| San Joaquin | 310 |
| Stanislaus | 310 |
| Merced | 244 |
| Average | 284 |
| Madera | 244 |
| Fresno | 330 |
| Kings | 410 |
| Tulare | 213 |
| Kern | 425 |
| Average | 324 |

¹Average TDS was calculated by county for the two references available and the high value of the two was selected to represent the county. References were: GAMA, 2007 and DWR, 2003.

The present salinity levels in groundwater are likely to go up as we have changed the hydrological system in California dramatically. We divert surface water supplies for use by agriculture, municipal and a variety of other uses and with it come the salts they contain. Plants, animals and humans use the water but leave the salts behind. The salts that remain behind either percolate to the groundwater and are re-pumped with groundwater supplies for the same type of uses or find their way back into surface water supplies. As areas import and store more and more salt, the ultimate impact is to the usability of the remaining water supplies, especially groundwater. Irrigated agriculture and dairies are part of this process and not only have to deal with salinity but also with increasing nitrate levels.

The Threat

Salinity is a critical problem throughout the state. In the densely urban coastal areas of California, salinity is frequently caused by ocean saltwater intrusion, a serious problem that can destroy beach city water supplies and coastal agriculture. The inland areas of California face a far different salinity problem. Imported or diverted surface water supplies or pumped groundwater needed to satisfy agricultural and domestic needs brings with it salts that stay in the soil and are eventually pushed down until they enter the groundwater. The groundwater concentration could increase until it can no longer meet beneficial uses including agriculture. Other areas of California are dealing with salt problems by developing and exporting or storing salt. Neither export nor storage is a cheap solution. One example is a regional 90-mile-long pipeline was built in the Santa

Ana area beginning in the 1970s to send saline wastewater from inland areas of San Bernardino and Riverside counties (including from dairies the Chino Basin) to the Pacific Ocean in Orange County. This facility for salt removal was a key effort to improve water quality in the Santa Ana Watershed (Western Water, 1999). The salt generated at dairies in the Chino and San Jacinto basins were considered in developing the final solution and in some cases it increases the cost of doing business in these basins. In the Imperial Valley, salt is exported and stored in the Salton Sea and the cost to maintain the sea is rising each year.

Because salts move with water all our actions affect the ultimate salinity levels we will need to address. In the future it is likely that, if left unchecked, salinity will:

- Significantly limit water resource management options especially during droughts;
- Reduce the productive life of soils for agriculture, reducing profitability;
- Impair surface and groundwater used for drinking, farming, industry, the environment and recreation;
- Endanger the economic vitality of certain areas of California, especially the Central Valley;
- Stall business and residential growth;
- Increase the costs of urban drinking water and wastewater treatment;
- Increase the cost to business for water-related compliance;
- Reduce the useful life of water pipes, appliances and equipment; and
- Increase wastewater treatment and compliance costs.

Impact of Dairies in the Central Valley

The Central Valley Regional Water Quality Control Board (Central Valley Water Board) and the State Water Resources Control Board and affected stakeholders have formed a Central Valley Salinity Policy Group (CV-SALTS). The group's task is to aid in development of a long-term, comprehensive salinity and nitrate management plan for various areas of the Central Valley of California (CVRWQCB, 2010). More information about the Salinity Policy Group is available at:

http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/index.shtml.

Numerous waste discharge regulatory orders adopted by Central Valley Water Board since the spring of 2007 have included requirements for the discharger to assess and identify practices that can be implemented to reduce or manage their salinity contribution.

The Central Valley of California is made up of two distinct valleys: Sacramento and San Joaquin. Tremendous diversity of land use activities exists in these valleys. The Sacramento Valley is largely agrarian, consisting of large tracts of irrigated agriculture with interspersed urban and dairy production areas. Both the surface and ground waters in the Sacramento Valley are of good quality and a key resource to users within the Sacramento Valley as well as the San Joaquin Valley and Southern California from water diverted from the Delta.

The San Joaquin Valley is also agrarian with large tracts of irrigated land, large urban centers, but with more intensive dairy production areas. Two distinct basins exist in the San Joaquin Valley. The northern most is the San Joaquin River Basin. Its river outlet is also to the Sacramento-San Joaquin Delta. The demands on water supply and use in this basin minimize actual flow of water from the Basin and thus minimize salt export. The salt export that does occur is causing increased salinity concentrations in the San Joaquin River and Delta. The Tulare Lake Basin is the southern most portion of the San Joaquin Valley. No outlet exists for ground waters, and an outlet for surface water exists only for short periods of time during high precipitation or flooding events. The result is that the natural salts in the surface water supplies spreads salts across the entire groundwater basin. In addition, the water supply in the entire Tulare Lake Basin is insufficient to meet the need given the level of development. A significant portion of the surface water supply is imported, either from the San Joaquin River or from the Sacramento Valley and with this imported water comes imported salts.

One primary reason the Central Valley Water Board is addressing salt and nitrate in more recently adopted waste discharge requirements is to identify methods to reduce the impact on ground and surface waters, thereby extending the useable lifespan of these water resources. The Central Valley Water Board is concerned about two key components related to salt and nitrate accumulation. The first is importation of salt into portions of the Central Valley. These imported salts contribute to the salt load accumulating in surface and ground water resources within the valley. Nearly all salts imported into the Tulare Lake Basin, in particular, accumulate in the groundwater. The goal of the Central Valley Water Board is to minimize this salt importation.

The second component is the overall accumulation of salt and nitrate in a localized geographic area, potentially creating a “hot spot” of highly concentrated salts or nitrate in underlying groundwater. The origin of this material, whether it is imported or originates within the basin is irrelevant. Continued accumulation of salts and nitrate in underlying groundwater may ultimately make the water unusable.

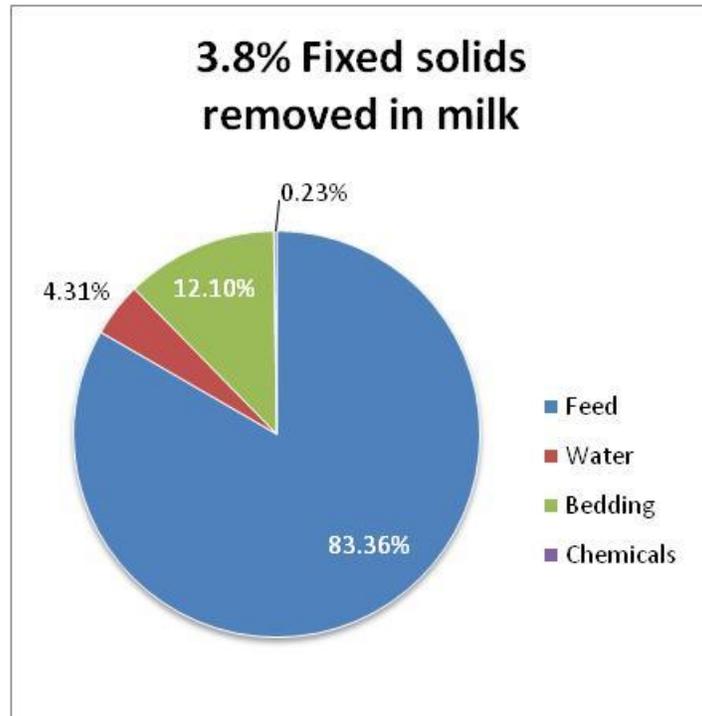
One of the orders adopted by Central Valley Water Board is a General Order for regulating waste discharges from Existing Milk Cow Dairies (Order) (CVRWQCB, 2007). This Order, adopted on May 3, 2007, established a staged implementation process designed to protect the waters of the state from degradation due to dairy practices and focused primarily on salts and nitrate.

As part of a staged implementation process for salinity control, the Order requires all dairies to assess their facilities’ salt inputs and identify ways of reducing the salt load that enters the waste stream. On page 22, the Order specifically requires that “*The Discharger (a dairy) shall submit a report that identifies sources of salt in waste generated at the dairy, evaluates measures that can be taken to minimize salt in the dairy waste, and certifies that they will implement the approved measures identified to minimize salt in the dairy waste.* Because most dairy operators do not have the resources or knowledge to conduct such an evaluation, the Order allowed a third party to prepare an industry-wide report that the dairy operator could refer to in preparing their own report. The University of California at Davis prepared such a document and it serves as a reference for dairy

operators and Certified Crop Advisors when preparing their own reports for compliance with the Order and scheduling crop nutrient applications (Berg et al., 2009). Each dairy operator and Certified Crop Advisor should review this report and understand where the main sources of salt are in the dairy.

The industry-wide report points to three types of salt on a dairy facility. Salts are imported as part of the regular activities of dairy production in feed, bedding, and chemicals, salts added to the dairy production facility such as dietary supplements added to ration(s) in excess of requirements, and salts already present such as in the water used for sanitation and animal hygiene and animal drinking and cooling water. The report shows that the majority of the salt load in a dairy facility is associated with the feed supply (Figure 1) (Berg et al., 2009).

Figure 1 Origin of salts on a typical dairy facility using the 96.2 Fixed Solids Index as defined in Berg et al., 2009



When salts need to be considered in developing a nutrient management plan, it may be necessary to reduce or limit salt inputs. UC Davis noted that there is minimal opportunity to reduce salts in the water supply without compromising animal health, well-being and production and that any salt reduction can only be accomplished through management of the dietary supplements and the feed sources. The report provides dairy operators a menu of measures which would reduce salt importation to their production areas and reduce salt loads in the waste stream that is applied for crop production.

It is not possible to avoid salts completely at dairy facilities. All feed sources, organic bedding constituents, waters and chemicals contain salts. The goal becomes for the dairy operator to manage these input sources to minimize importation of salt onto the facility and where needed to work in concert with certified cropping specialists to minimize the impact of the remaining salt on surface and groundwater supplies.

The CV-SALTS process started by the State Water Board, the Central Valley Water Board and a coalition of stakeholders will lay out the long-term needs for salt management. The continuing challenge for the dairy operators and certified crop specialists is to develop, demonstrate and implement practices for manure and wastewater handling in the land application areas that protect the ground and surface water supplies.

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Proper Design of Dairy Liquid Manure Nutrient Distribution Systems to Facilitate Agronomic Applications

Micah Bowman, Professional Engineer
Provost & Pritchard Consulting Group
130 North Garden Street, Visalia, CA 93291
(559) 636-1166, mbowman@ppeng.com

Introduction

With the California Regional Water Quality Control Board's (**Water Board**) adoption of the Waste Discharge Requirements General Order for Existing Milk Cow Dairies, Order No. R5-2007-0035 (**General Order**) and the July 1, 2012 Nutrient Management Plan (**NMP**) implementation deadline, the dairy industry has seen an increased need for precision application of nutrients to crops. Under the General Order, dairies are required to implement a NMP prepared by a Certified Crop Advisor (**CCA**), professional Soil Scientist, Agronomist or NRCS certified Technical Service Provider (**TSP**).

The intent of the NMP is to provide the farmer a schedule of when to apply specified quantities of nutrient laden water from the dairy to crops in order to meet a nitrogen ratio of 1.4 (nitrogen pounds applied to nitrogen pounds removed). A properly designed dairy liquid manure nutrient distribution system provides dairies the ability to implement their NMP. Precise amounts of nutrient laden water from the dairy can be distributed to discrete mixing stations throughout the farm for crop utilization. Agronomic applications should not be limited by infrastructure, but should instead be facilitated by it.

Water Generation and Quality

A properly designed nutrient distribution system begins with understanding the quality and volume of water generated by the dairy. Daily barn water generation is a large variable needed for determining volumes. Cooling equipment, sprinklers, and floor flushing from the dairy barn can vary greatly from dairy to dairy. Other components of the total water generation are rainfall & evaporation. **Figure 1** illustrates the various components of a typical flushed dairy facility where water is generated and used.

To understand the quality of the water generated, a representative lagoon water samples will be needed. Currently the Water Board requires quarterly sampling of the lagoon water. The concentration of nutrients in the lagoon varies throughout the year. During the winter months the cooler weather inhibits microbial action in the lagoons. Also, if cows are housed in freestalls as opposed to open corrals more nutrients are collected. During the summer, many dairymen add irrigation water to their lagoons in order to flush out some of the solids built up from the winter. By doing so, this reduces the concentration of the lagoon water nutrients but increases the volume of lagoon water. By analyzing samples quarterly, differences and trends between summer and winter applications can be determined. Ultimately, the designer must design the system to handle the total volume generated, and to deliver the nutrients that the crop needs.

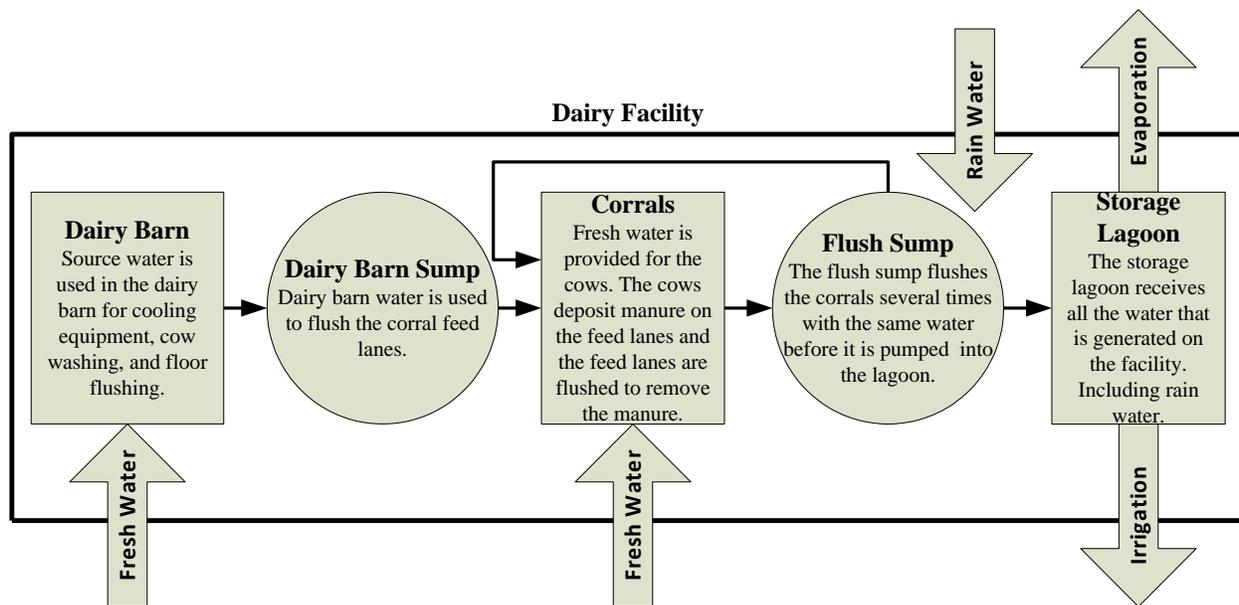


Figure 1. The diagram of the dairy facility shows the path that water takes through the different areas of the facility and its uses. The fresh water source is typically from a groundwater well. Rain water falls across the entire facility and much of it drains into the lagoon. The lagoon water is evaporated and used as irrigation water for crops.

Lagoon Management

Knowing the fill rate of the lagoon, the nutrient load within that volume, and the size of the lagoon, the number of needed irrigations throughout the year can be determined. For Central Valley dairies, the predominant crop rotation is corn in the summer months and wheat in the winter months. On a mass balance basis, dividing the total pounds of nitrogen produced by the agronomic nitrogen demand of the crops determines the total acreage needed for nutrient utilization. The calculated acreage can be reduced to reach the 1.4 nitrogen ratio. Balancing the nutrient needs and uptake timing of the crop with the lagoon capacity results in the number of irrigations needed. **Figure 2** illustrates the lagoon storage volume throughout the year for a typical properly designed system on a dairy facility.

Often times, the lagoon water is applied less frequently but in larger volumes, which may not be as beneficial to the crop. Typically the reason for this type of irrigation is because the lagoon pumps have a high flow rate (as much as 1,200 gallons per minute (**gpm**) or higher). Using a lagoon pump with a high flow rate is difficult to evenly spread across the entire field, because of the need for a large volume of additional well water. It is also difficult to apply the proper concentrations of crop nutrients evenly across the field. For instance, the volume of water delivered to a field that takes 14 days to irrigate with a 1,200 gpm pump is approximately 3.2 million cubic feet. From **Figure 2** referring to the infrequent, large volume irrigations, the volume of one irrigation is approximately 2.5 million cubic feet. Applying the lagoon water in this manner can be detrimental to the crop. Water with a high Biological Oxygen Demand (**BOD**) can deprive the crop roots of O_2 , which can affect the plant's growth. Furthermore, if more nitrogen is applied than the crop needs the next irrigation will push the remaining nitrogen down below the root zone. This is the concern of the Water Board and the basis for the 1.4

nitrogen ratio. The effect of this type of application scenario on the lagoon storage capacity is illustrated in Figure 2 with the solid line. The four irrigation events results in a maximum storage volume of approximately 3.25 million gallons.

If each of the four larger irrigation events were divided into four smaller events, the maximum storage volume is reduced to approximately 1.4 million gallons; a reduction of approximately 56%. Referring to Figure 2, this type of irrigation scheduling is illustrated by the dashed line. In order to achieve the more frequent irrigation scheduling a lower flow rate pump is required.

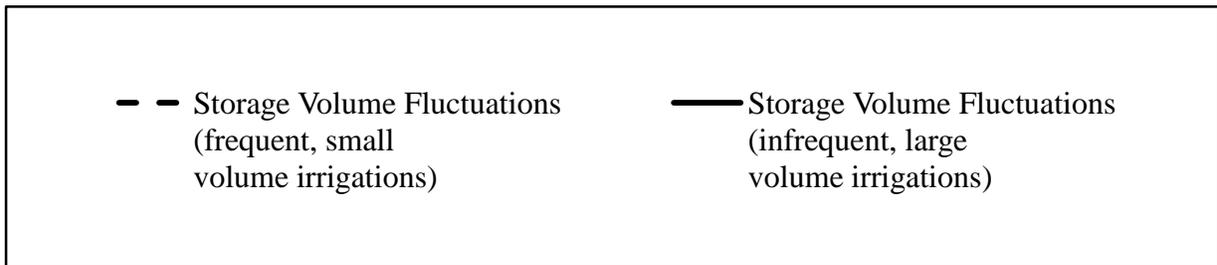
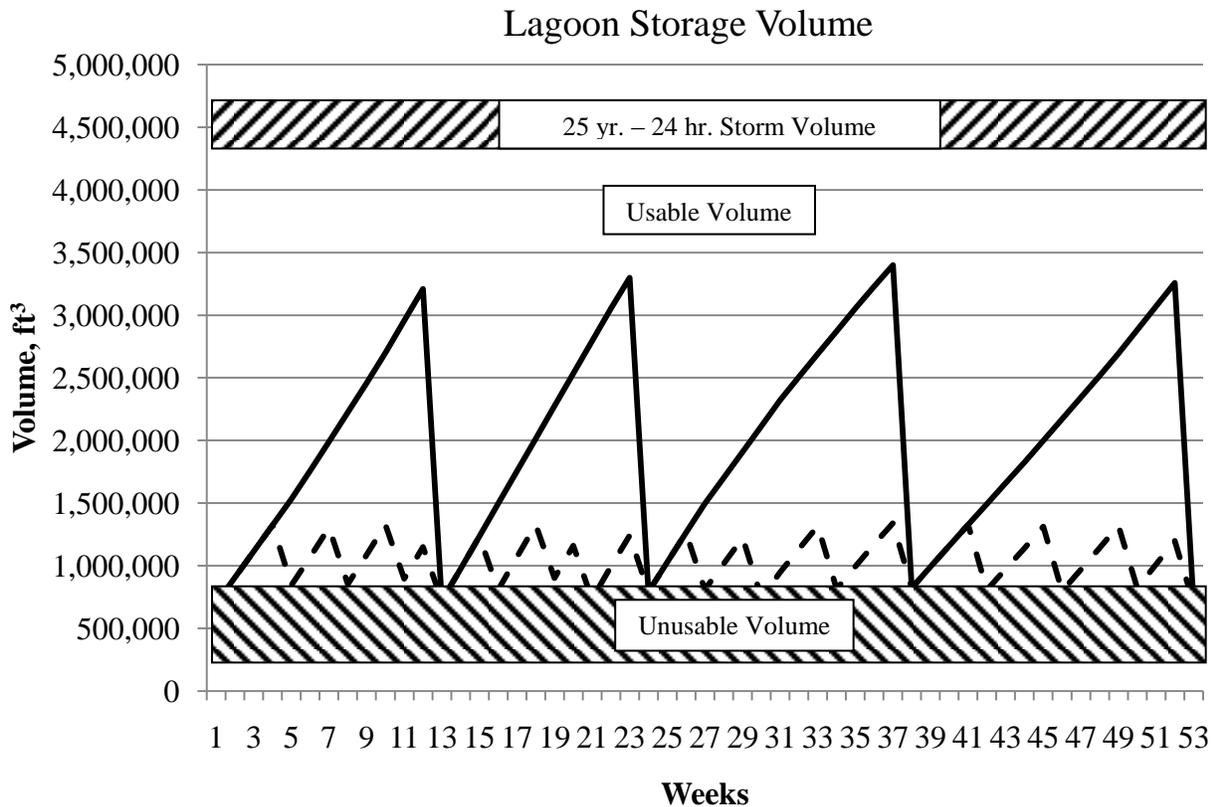


Figure 2. Lagoon storage volume graph with various components of storage. The unusable volume is due to the pump being unable to operate at a depth lower than 5 feet. The usable volume of the lagoon is the difference between the unusable volume and the 25 yr., 24 hr. storm.

Mixing Stations and Mixing Zones

When evaluating the available acreage, mixing stations and mixing zones can be determined based on the farmer's irrigation system and management style. Mixing stations should be located in conjunction with irrigation wells serving a group of fields or mixing zones. The mixing of fresh irrigation water and lagoon water is best accomplished in large standpipes. Mixing in this manner, as opposed to in a pipeline, provides adequate mixing of the two liquid streams without creating a pipeline head-to-head flow situation. The fresh water from the well can be delivered over the top of the standpipe to allow for proper air gap separation. **Figure 3** depicts the layout of a typical mixing station. Mixing of fresh water from a canal can be accomplished in much the same manner but care should be taken to prevent lagoon water from entering the canal with the use of a lift pump out of the canal and into the top of the standpipe. The lagoon water pipeline does not need an air gap and can penetrate the side of the standpipe or be delivered over the top. Adequate mixing is important so that the nutrients can be evenly distributed throughout the fields; however, measures should be taken to control the generation of foam.

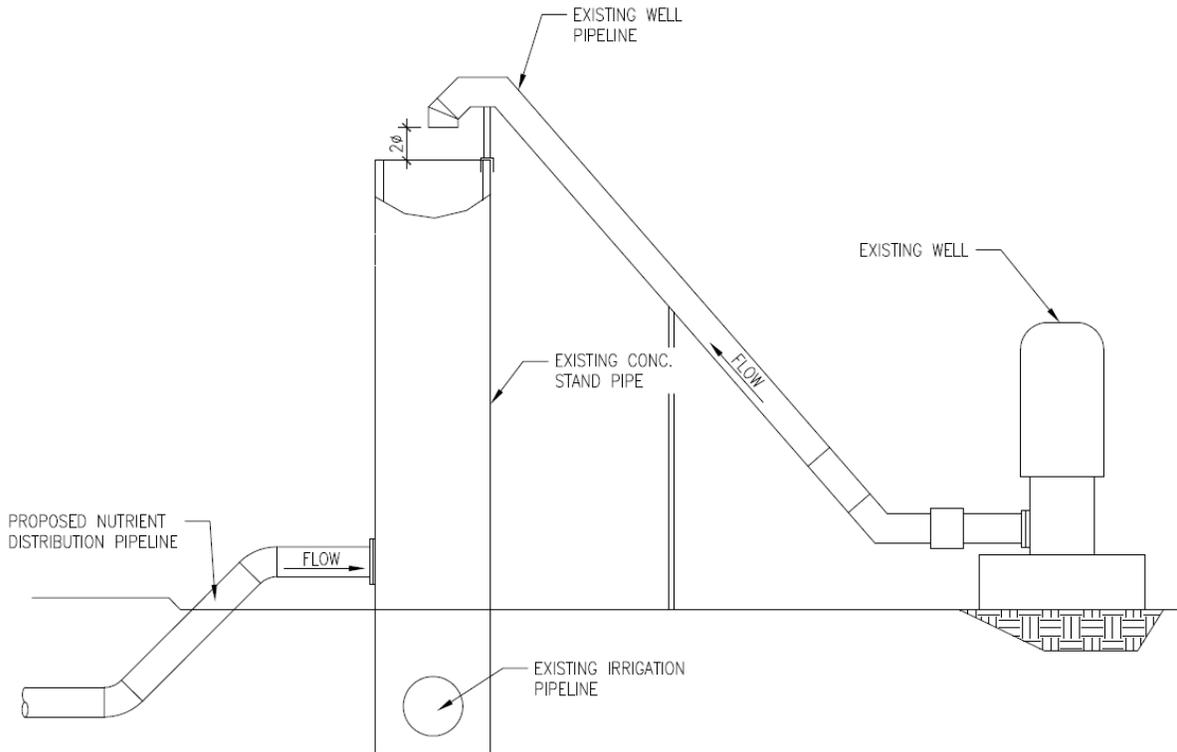


Figure 3. Mixing station layout with air gap to prevent contamination of well.

After locating the mixing stations and mixing zones, the farming practices are analyzed. Some of the information gathered includes the advance rate of the water across the field, the amount of water applied per irrigation, and the number of irrigations per season. This information is used to determine the operation and performance of the system. Also, the NMP is reviewed and the agronomist is consulted to determine the agronomic demands of the crops, and nutrient applications to correspond with the needed irrigation schedule.

Pipeline Appurtenances

Robust and redundant equipment like valves and air vents are important for the system to function properly. Two combination air/vacuum relief vents are installed at each location along the pipeline to ensure protection in case one of them becomes plugged. Air vents are placed at high points, after pump check valves, and every 1,320 feet. Although a properly designed system minimizes the likelihood of plugging, installing clean outs and/or designing the system to back flush can reduce overall operation and maintenance costs. The use of V-notch gate valves allow the flow to be throttled with the benefit of minimizing the potential for plugging. A V-notch gate valve changes the cross section of the valve from circular to triangular. The triangular cross section leaves a larger opening when the valve is closed. **Figure 4** illustrates the cross sectional opening of a V-notch gate valve versus a typical gate valve with a circular cross section.

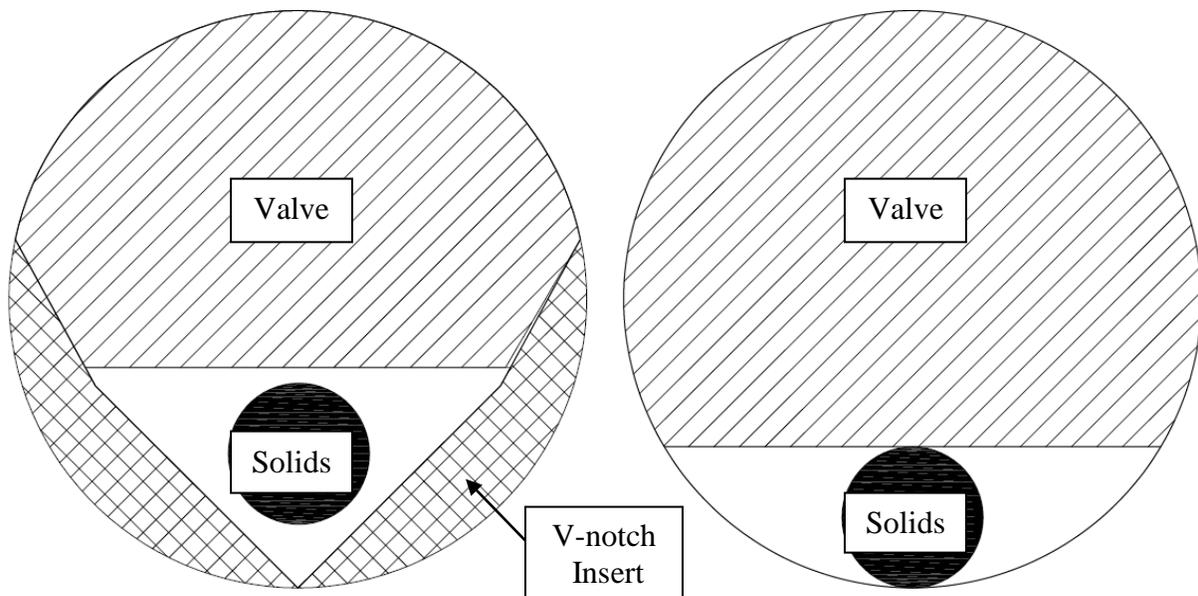


Figure 4. The illustration shows the cross sections of a V-notch gate valve (left) and a regular gate valve (right). The horizontal line is the bottom of the gate. Both openings have the same cross sectional area; however, the V-notch gate valve can allow larger diameter solids to pass compared to the regular gate valve. In this illustration the solid material (depicted as a circle) has a 2 inch diameter and fits through the V-notch gate valve easier than the circular gate valve.

Flow Rate Significance

The most significant characteristic of the system is the flow rate. It determines the diameter of the pipeline, the horsepower of the pump, and the nitrogen application rate (lbs per acre). There are several factors that go into calculating the flow rate including: the advance rate of the fresh water across the field, the total volume of water generated, and the acreage needed for nutrient utilization. The variable in the calculation for the flow rate is the number of irrigations per year with the lagoon water. The final flow rate selection is based on: the crops maximum nitrogen application in a single irrigation and the cost of the system. The maximum nitrogen application in a single irrigation for corn and wheat is approximately 80 pounds per acre. Knowing the

concentration of the nitrogen in the lagoon water and the nitrogen application rate will lead you to the maximum flow rate.

Using the flow rate, the diameter of the pipeline is calculated based on minimum and maximum velocity guidelines of 2 feet per second and 5 feet per second. The minimum velocity is to prevent solids from settling out and plugging the pipeline. The maximum velocity is to protect the pipeline from damage caused by water hammer, excessive friction loss and higher energy costs. The maximum velocity will result in a smaller pipeline while the minimum velocity will result in a larger diameter; if the flow rate is small enough.

With the pipeline sized and the flow rate determined, the hydraulics of the system can be calculated for the various scenarios. The pump is selected based on the system curve, which is a plot of energy versus flow rate for each scenario. Although a smaller pipeline will cost less than a larger pipeline; the pumping cost will be greater due to higher pressures required to overcome friction losses. For both pipeline options the velocities for all the scenarios should be analyzed for adequacy and a cost analysis performed before the design is finalized.

Conclusion

There are many benefits for a dairy facility to have an efficient and effective nutrient distribution system. Applying the lagoon water frequently in smaller amounts minimizes the facility's required lagoon storage capacity. Through the efficient application of nutrients, significant savings from the reduction of commercial fertilizer and the benefits from increased yields are realized. A properly designed system also simplifies the irrigator's job, which can reduce operator error when following the NMP.

A Review of the Central Valley Dairy Representative Monitoring Program

Till E. Angermann, Vicki Kretsinger Grabert, Barbara Dalgish
Luhdorff and Scalmanini Consulting Engineers
500 First Street, Woodland, CA 95695
Phone (530) 661-0109, Fax (530) 661-6806,
teangermann@lsce.com

Introduction

In May 2007, the Central Valley Regional Water Quality Control Board (CVRWQCB) adopted Waste Discharge Requirements General Order No. R5-2007-0035 for Existing Milk Cow Dairies (CVRWQCB, 2007). The goal of the General Order is to protect groundwater resources. The General Order imposes significantly more stringent requirements than were previously mandated, including the installation of monitoring wells on all existing dairies to identify whether dairy farm practices are protective of groundwater. The prospect of installing monitoring wells for regulatory compliance purposes on over 1,400 dairies in the Central Valley is discouraging because it would likely span 10 years or more and generate an overwhelming quantity of redundant data.

In February 2011, the CVRWQCB adopted a revised Monitoring and Reporting Program (MRP), which allows for representative groundwater monitoring as an alternative to the site-by-site approach (CVRWQCB, 2011). In September 2011, the CVRWQCB conditionally approved the Phase 1 Representative Monitoring Program Workplan (LSCE, 2011). Phase 1 RMP refers to the initiation of a network of 126 dedicated monitoring wells distributed over 18 dairies in Stanislaus and Merced Counties. The Phase 1 RMP Workplan details a proposed plan for (i) the installation of a network of dedicated monitoring wells, (ii) systematic development of a comprehensive data set, (iii) centralized data collection and compilation, (iv) uniform quality assurance (QA) and control (QC), (v) comprehensive data analysis, evaluation, and reporting, (vi) ongoing refinement of the RMP, (vii) the formation of external advisory committees and development of Best Practicable Treatment or Control (BPTC) practices, (viii) stakeholder input, and (ix) the geographic expansion of the RMP in Phase 2.

The RMP is managed by the Central Valley Dairy Representative Monitoring Program (CVDRMP), a non-profit California corporation managed by a 12-member board of directors, and supported by approximately 1,190 member dairies (as of November 2011).

Concept of the RMP

The goal of the RMP is to identify whether dairy farm practices are protective of groundwater by using a data collection and analysis effort that uses a subset of dairy farms and assesses the effects associated with specific management units (i.e., the manured forage fields, corrals, and liquid manure holding ponds). Inherent in this approach is the extrapolation of results to non-monitored dairies. The ability to extrapolate monitoring results from dairy farms monitored under the RMP to non-monitored dairy farms rests on the selection of (i) physical parameters that control subsurface loading and (ii) dairy farm infrastructure and operational characteristics. The subsurface loading rate is determined by the product of its two components, the rate of deep percolation (i.e., the amount of infiltrated water reaching first encountered groundwater) and the

constituent concentration of the infiltrate. It is a chemical flux that describes a particular management unit's performance. This is a universal concept applicable to any management unit.

Physical parameters directly support the analysis and interpretation of groundwater quality data. As such, these parameters are key to the representativeness of the RMP. Some physical parameters are largely independent of dairy operational decisions and management, and they cannot be readily changed by individual dairy farm practices. These parameters are referred to as "static" in this context (e.g., soil texture and precipitation). The overall depth to groundwater is also a physical parameter, which is largely independent of individual farmers' dairy operational decisions and management. However, the depth to groundwater does not control subsurface loading, it merely affects the travel time of the infiltrate through the unsaturated zone and, thus, exerts control on the response time between surface processes and groundwater quality responses (reactive transport is not considered at this time).

Physical parameters that can be addressed via management practices are referred to as "dynamic". The irrigation rate and duration, manure and fertilizer application, and crop type are examples of parameters important for the groundwater quality evaluation beneath manured forage fields. Examples for corrals are ground surface slope (to provide drainage), degree of compaction, and extent and duration of standing or pooled rain water. Examples for liquid manure storage ponds are ultimately (and most directly) the seepage rate and constituent concentrations (i.e., the components of the chemical flux).

In contrast to physical parameters, dairy farm infrastructure and operational characteristics do not have a direct bearing on the analysis and interpretation of groundwater quality data, because they do not provide information on actual subsurface loading rates. Examples include (i) the dairy farm size, (ii) number of lactating milk cows, dry cows, or heifers, etc., and (iii) the relationship between annual manure exports and imports of synthetic fertilizers. Specifically, dairy farm size (including the total cropping area available for manure application) in absolute terms or in relation to the total number of animals on the farm does not provide an indication of actual nitrogen and salt application rates occurring on any particular forage field. Similarly, the relationship between annual manure exports and imports of synthetic fertilizers is insufficient to explain any particular constituent concentration in a groundwater sample obtained from a particular monitoring well. From an infrastructure and operational standpoint, non-monitored dairies exhibiting comparable characteristics are expected to be able to implement similar management practices that are determined to result in groundwater quality improvements on monitored farms. As such, the diversity of these parameters in the group of monitored dairies is key to the implementability of identified management practices on non-monitored dairies.

Dairy Farm Selection for Phase 1 RMP

It is critical to the success of the RMP that a causal link be established between groundwater quality changes in response to modifications to dairy management practices. The shorter the response time the higher the confidence in the identified linkage between management practices and groundwater quality trends, and the sooner conclusions can be drawn from the data. Therefore, in terms of static physical parameters, the Phase 1 RMP emphasized implementation in an area characterized by sandy, highly permeable soils and shallow depth to groundwater in Stanislaus and Merced Counties between the San Joaquin River and Highway 99 (i.e., the high

priority area identified in LSCE [2010]). To increase the representativeness of the Phase 1 data collection effort, the Phase 1 RMP Workplan monitoring network also extends west of the San Joaquin River into an area of shallow groundwater and clay-rich, low permeability soils. In terms of dynamic physical parameters, Phase 1 dairy farms were selected to include forage crops typical for the industry (e.g., corn, oats, alfalfa, sudan, pasture, and wheat). Likewise, the initial Phase 1 RMP dairy farm group employs typical irrigation practices for their forage crops, namely border and furrow irrigation. Crop fertilization occurs by use of synthetic fertilizers, and both liquid and dry manure. Corrals were selected to exhibit a range of slopes and surface conditions. Earthen liquid manure storage pond systems on most of the selected dairies include one or more settling basins and a main storage pond. Some of the selected dairy farms utilize mechanical solids separators in addition to settling basins. Others operate a mechanical separator with a single liquid manure storage pond. Solids removal from settling basins occurs mostly via scooping off the dry top layer but may also include more complete drying and/or deeper excavation. Solids from the main storage ponds are removed either via agitation and pumping, or excavation, or may not yet have been necessary at the time of the site visit. Liquid manure storage facilities range in depth from 4 to over 20 feet, and many are older than 10 years. Phase 1 dairy farm infrastructure and operational characteristics include the following:

- farm size ranges from approximately 550 to 5,500 mature milk cows;
- animal housing occurs to approximately equal portions under roofed areas (freestalls) and open lots;
- additional infrastructure includes separate areas for heifers, calves, dry cows, bulls, and sick animals; milk barn; loading docks and roads; hay and commodity barns; outside silage storage; manure drying/stacking areas; farm equipment yards and machine shops; residential housing; ditches and underground pipelines; and tailwater recovery systems;
- mature milk cows constitute approximately half of all animals on the dairy farms;
- predominant waste management via flush lanes but also substantial manure drying;
- proportion and absolute volume of manure exports vary widely between dairies;
- the overall size of the land application areas varies widely between dairies and is not correlated to the number of animals; and
- reported whole farm nitrogen-balances range from less than 1.00 to over 3.00.

Groundwater Monitoring on Dairies

Groundwater monitoring efforts target the uppermost zone of first encountered groundwater. There are two notable differences between traditional groundwater monitoring of regulated units (e.g., as applicable to the Environmental Protection Agency's Underground Storage Tank Program, landfills, wastewater treatment plants, and other industries) and groundwater monitoring on dairy farms. First, traditional regulated units are designed to not recharge groundwater, whereas irrigated agriculture depends on sufficient leaching of salts beyond the crop root zone to avoid increasing soil salinity and associated soil degradation and crop losses (and some recharge is also expected from corrals and liquid manure storage ponds). This recharge introduces a vertical downward flow component in shallow groundwater. Therefore, groundwater samples retrieved from upgradient and downgradient monitoring wells will not originate from the same source areas but from different source areas (i.e., the area contributing flow to the well). Second, constituents of concern related to traditional regulated units are not commonly found in natural groundwater systems (e.g., petroleum products), and a detection in a

downgradient well provides evidence that the regulated unit leaks (given that this constituent is not detected in the upgradient well). This is in contrast to irrigated agriculture, where constituents of concern (i.e., mainly nitrate and other salts) are ubiquitous in the local groundwater system. The circumstances under which groundwater monitoring is conducted in areas of irrigated agriculture have the following implications for monitoring well design, data collection, and data interpretation:

- RMP monitoring wells positioned downgradient of a management unit are aimed to be constructed such that they intercept groundwater, which originates under that targeted management unit, only.
- Groundwater sampling should occur in the upper few feet of the groundwater column to avoid mixing of (younger) groundwater originating under the targeted management unit with (older) groundwater from source areas upgradient of the targeted management unit.
- As a corollary to the above, the concept of comparing downgradient to upgradient groundwater quality as a means to determine potential groundwater degradation loses its utility in recharge-dominated systems.

For purposes of the Phase 1 RMP, the above design challenges were addressed by (i) placing wells in areas of shallow groundwater and relatively small seasonal groundwater level fluctuations and (ii) constructing nested wells (i.e., two well casings with relatively short well screens located at different depth intervals, constructed in one bore hole). The nested monitoring well design provides monitoring facilities that:

- address uncertainty regarding the extent of the source area;
- are better suited to address seasonal and longer-term groundwater level fluctuations than single-completion monitoring wells;
- are suitable for the installation of shorter screen lengths (e.g., 5-15 feet), which helps avoid potential groundwater quality bias due to vertical flow components in the wells; and
- can be used for chemical groundwater profiling including isotopic groundwater age dating.

Formation of External Advisory Committees

The formation of two advisory committees is planned; Technical Advisory Committee (GTAC) and a Multidisciplinary Advisory Committee (MAC). The purpose of the GTAC is to ensure adequacy of the RMP data collection effort and the soundness of analytical tools and interpretations. It is envisioned that this committee will include, for example, hydrologists, statisticians with experience in environmental applications relevant to this work effort, members of the University of California Cooperative Extension Hydrology Program, dairy farm representatives, and CVRWQCB staff and additional professionals as determined appropriate by CVDRMP. Members of the GTAC will be asked to critically review and formally comment on draft annual reports before their finalization. The GTAC review and comment process is to facilitate delivery of comprehensive work products (particularly annual reports) submitted to the CVRWQCB.

It is envisioned that the MAC will include professionals with backgrounds in agronomy, economy, animal nutrition, irrigation, plant biology, hydrology, and civil engineering (with emphasis on liquid manure storage pond design, pond liners and covers, wastewater treatment,

and digester technology). The MAC would also include members of the University of California Cooperative Extension Hydrology Program, dairy farm representatives, and CVRWQCB staff, and others as deemed appropriate by CVDRMP. The purpose of the MAC is to:

- Aid in the compilation of a list of existing management practices, which will be used in the refinement of the RMP and affect both the extrapolation of RMP findings to non-monitored facilities and the expansion of the RMP;
- identify innovative methodologies, approaches, and analytical tools (e.g., whole farm nitrogen use efficiency modeling, modeling of nitrogen and salt movement in the root zone, and groundwater modeling) to support the RMP and its goals;
- review and evaluate results from implemented methodologies, approaches, and analytical tools;
- identify potential research needs; and
- identify potential solutions in response to findings of the RMP.

Continued Stakeholder Input

Public stakeholder meetings are planned to continue. The purpose of these stakeholder meetings is to:

- inform stakeholder groups of the progress and development of the RMP;
- inform stakeholder groups on key findings of the RMP that are presented in Annual Reports;
- provide a platform to discuss findings and answer questions; and
- provide a platform for public input and external review from interested parties.

Refinement

The RMP will be assessed on an annual basis and dynamically modified through a process of peer review, input from technical advisory committees (GTAC and MAC), and stakeholder input.

Phase 2 RMP

Phase 2 RMP refers to the geographic expansion of the RMP to all San Joaquin Valley Counties, and selected counties in the Sacramento Valley, where dairy farming occurs. Phase 2 will be addressed in a separate Phase 2 RMP Workplan.

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American Society of Agronomy

California Chapter

Session VI
BMP's for Carbon and
Nutrient Dynamics

Session Chairs:
Dave Goorahoo
Toby O'Geen

Synchronizing Soil Biology with BMPs: The Future of Carbon and Nutrient Management

Bruce A. Roberts, Department of Plant Science, CSU Fresno
2415 East San Ramon Avenue M/S AS72, Fresno, CA 93740-8033
Phone (559) 278-1758, baroberts@csufresno.edu

The complexity of soil biology challenges our human imagination. Where soil chemistry and physics are more defined by laws governing these established disciplines, soil biology – made up of numerous organisms ranging across scales in size and activity by orders of magnitude, many of which are not fully understood – is still an area of active discovery. How we synchronize even the simplest soil web (an association of organisms making a biological food chain or linkage) into a reliable agronomic process using best management practices is still crude by our current standards of efficiency. Data from studies using mass balance of input/output ratios show there is still room for fertilizer efficiency improvements. Depending on crop and soil types values of nitrogen efficiency range from less than 50 to 85 percent. Can we utilize Best/Better Management Practices in the future to meet the world's increasing need for food and fiber? Indeed, this is the challenge of the future. Along with a changing environment and greater restrictions on nutrient sources and regulations, our best management practices will have to incorporate fundamental biological processes, as complex as they may be, into future management strategies and practices.

Recognizing agricultural systems have long been held to be nutrient limited, mostly nitrogen limited in terrestrial systems where productivity is the measured criteria of environmental services. However, soil biology – specifically microbial activity related to mineralization and nutrient turnover rates may also be directly linked to carbon limitations. Hence soils may be more response dependent to inputs of rotational crop residues or other organic/inorganic nutrient sources. Best management practices may have to reconsider organic inputs from cropping sequences and other nutrient sources to optimize biological activity in nutrient utilization efficiency.

Research on cotton nitrogen nutrition illustrates how differently soils respond to varying fertility levels based on soil textural properties. In addition to water management differences, soil textural habitats can influence microbial community structures and mineralization potentials contributing to significantly different fertilizer responses by soil types that can overwhelm management practices. Microbial mineralization is an important driving factor in meeting crop demands for more efficient production while operating within nutrient management plans designed to use animal manures, organic or inorganic nutrient inputs. A little information on this basic soil function could improve the synchronization of organic residue turnover and nutrient utilization.

How we synchronize basic soil biological processes with optimum plant uptake to sustain efficient and productive yields is the basis of a judicious nutrition program and best management practices in application. It's not always easy to do, but is essential to achieve production levels necessary to feed future generations. Without the use of fertilizers and soil/plant monitoring techniques and application technology crop yields would be reduced in areas of both short and

long season cropping. Extending the use of these agronomic tools and practices in developing countries will improve agricultural productivity around the world. Good agronomic production strategies are essential to augment agriculturally managed soil capacity to supply nutrients for optimum, efficient agricultural production. Future regulations on nutrient management based on soil physical, chemical and biological potentials will make for better management practices.

Current practices aiming to achieve improved efficiency will be discussed and include:

- Soil and plant tissue sampling
- Feed-back applications (based on the above information)
- Guidelines for seasonal applications (short term)
- Following crop recommendations (long term)
- Site specific applications (Precision Agriculture)
- Foliar, top-dressing, and water run applications (fine-tuning approach)

Future changes that could require modifications in our current practices may include:

- Genetic modifications for nutrient uptake efficiencies
- Soil mineralization estimates (soil quick tests)
- Mandated regulations on nutrient applications

Developing new best management practices aimed to improve nutrient uptake efficiency and conserve the long-term productivity of agricultural soils is the goal of modern agriculture. Assimilating more basic understanding of soil biology and ecology in crop nutrition practices will help improve future efforts in balancing the carbon and nutrient cycling in agricultural soils for efficient and sustainable productivity.

Nitrous Oxide Emissions from Selected Corn and Cotton Cropping Systems

Dave Goorahoo*^{1,2}, Florence Cassel S.^{1,2}, Shawn Ashkan², and Bruce Roberts¹

¹Department of Plant Science and ²Center for Irrigation Technology (CIT)

California State University- Fresno

2415 East San Ramon Avenue M/S AS72, Fresno, CA 93740-8033

*Phone (559) 278-8448, dgooraho@csufresno.edu

*Contact for presenting author

Introduction

The effects of the anthropogenic increase in atmospheric greenhouse gas (GHG) concentrations on climate change are beyond dispute (IPCC, 2007), and agriculture does play a key role in this issue, both as a source and a potential sink for GHG (California Energy Commission, CEC, 2005). Of the three biogenic GHGs (i.e., carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O)) contributing to radiative forcing in agriculture, N₂O is the most important GHG to be considered, researched, and eventually controlled within intensive and alternative cropping systems. It is estimated that in California, agricultural soils account for 64% of the total N₂O emissions, and N₂O may contribute as much as 50% to the total net agricultural greenhouse gas emissions (CEC, 2005). However, the reliability of these estimates is highly uncertain, which stems, in part, from a lack field measurements in California (CEC, 2005; EPA 2004), and in part, from the inherently high temporal variability of N₂O flux from soils. In a statistical analysis of 1125 N₂O studies from all over the world, the average 95% confidence interval was -51% to +107% (Stehfest and Bouwman, 2006). Among California's statewide greenhouse gas emissions, the magnitude of N₂O emissions is the most uncertain (CEC 2005).

Episodes of high N₂O fluxes are often related to soil management events like N fertilization, irrigation, or incorporation of crop residue, but the magnitude of the responses to such field operations also depends on soil physical and chemical factors, climate and crop system. The overall goal of our ongoing projects is to determine detailed time series of N₂O fluxes and underlying factors at crucial management events (irrigation, fertilization, etc.) in representative agro-ecosystems in Central Valley of California. For this presentation, we focus on the efforts aimed at the determination of N₂O flux measurements for silage corn and cotton cropping systems grown in the central San Joaquin Valley (SJV). The material summarized below represent results obtained from the first round of our ongoing study to estimate N₂O emissions from these crops. Much of the statistical data analyses are still in progress and will be published at a later date after peer review.

Description, Preliminary Results & Future Work

A system's approach that considers N fertilization, crop N use, N loss as N₂O, and the soil physical and chemical environment is being employed to determine the percentage of N lost to the atmosphere as N₂O from added N fertilizer. We anticipate that through intensive measurements of N₂O flux in the field for two consecutive years during periods with high N₂O emission potential, and less frequent, but regular monitoring of N₂O emissions when fluxes are low, baseline and event related N₂O emission will be calculated for each N addition treatment and crop system.

During the 2011 summer months we collected samples from five sites (A to G) with the general description and specific objectives as follows:

- Site A- Silage Corn:** Location: Hanford, CA ; Crop/Variety: Corn/Dekalb RX940RR2; Soil Type: Fancher’s Sandy Loam, Furrow irrigated.
Objective: To determine of N₂O fluxes following fertilization and irrigation events for silage corn fertilized with dairy effluent.
- Site B- Silage Corn:** Location: Hanford, CA ; Crop/Variety: Corn/Dekalb RX940RR2; Soil Type: Fancher’s Sandy Loam, Furrow irrigated.
Objective: To determine of N₂O fluxes following fertilization and irrigation events for silage corn fertilized with Urea Ammonium Nitrate (UAN 32).
Sampling: Flux chamber measurements conducted using an Environmental Protection Agency (EPA) approved methodology to collect air samples analyzed (ppm data) which are ultimately analyzed using a Gas Chromatograph (G.C.).

Results:

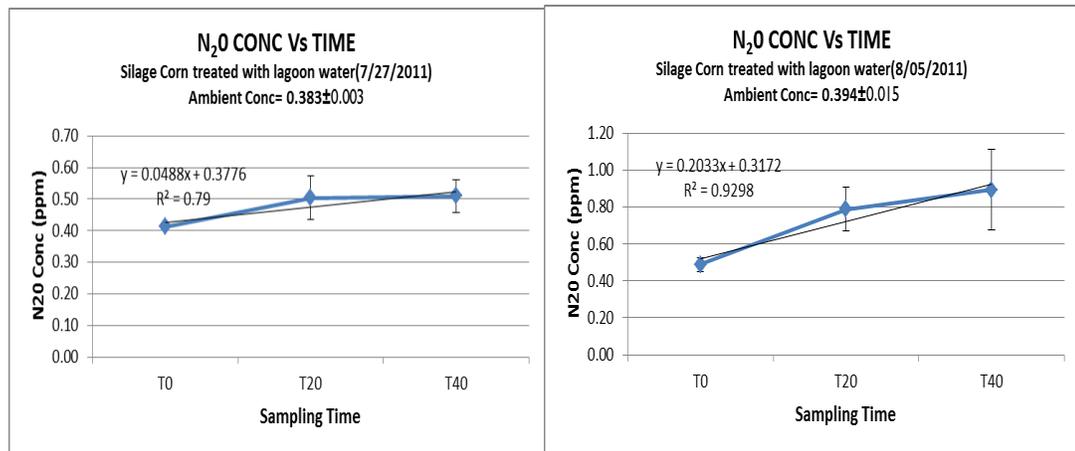


Figure 1: Example of N₂O concentrations measured at site A.

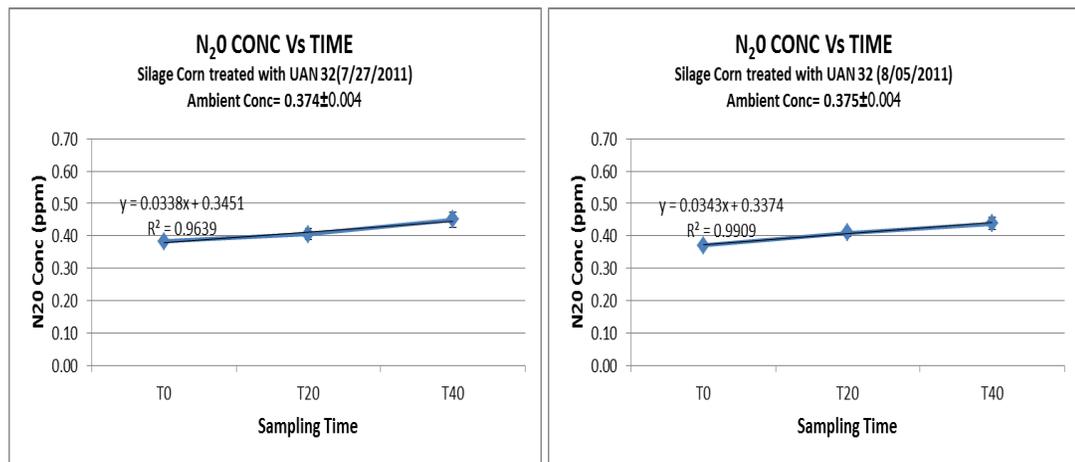


Figure 2: Example of N₂O concentrations measured at site B.

Future Work: Flux chamber measurements to be conducted after harvest; Soil samples to be analyzed for C and N contents; N₂O ppm data to be converted to flux values; Incorporation of data into Denitrification_Decomposition (DNDC) model; and, Comparison of measured values with those predicted from DNDC simulations.

- Site C- Cotton:** Location: Hanford, CA; Crop/Variety: Cotton/Acala; Soil Type: Fancher’s Sandy Loam, Furrow irrigated.
Objective: To determine of N₂O fluxes following fertilization and irrigation events for cotton with Urea Ammonium Nitrate (UAN 32).
Sampling: Flux chamber measurements conducted in furrows and beds and air samples analyzed (ppm data) using the Gas Chromatograph (G.C).

Results:

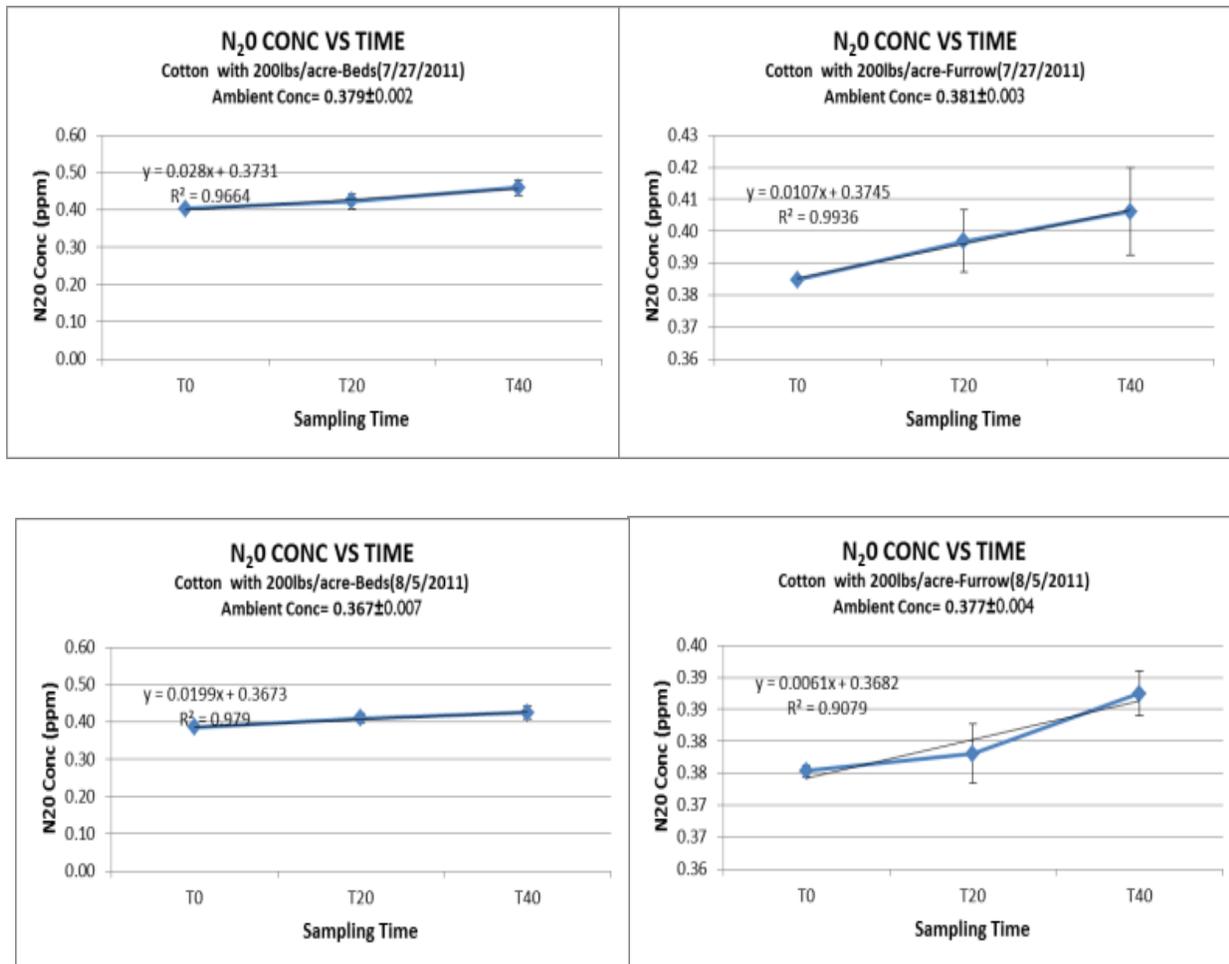


Figure 3: Example of N₂O concentrations measured at site C.

Future Work: Flux chamber measurements to be conducted after harvest; Soil samples to be analyzed for C and N contents; N₂O ppm data to be converted to flux values; Incorporation of data into DNDC model; and, Comparison of measured values with those predicted from DNDC simulations.

- Site D- Silage:** Location: Fresno, CA; Crop-Corn; Soil Type: Sandy Loam, Furrow irrigated.

Objective: Comparison of soil N₂O concentrations measured in silage corn with flux chambers and the INNOVA 1412 device (Figure 4).

Sampling: Two sampling events conducted during summer 2011. Comparison of data to be conducted during Fall 2011.

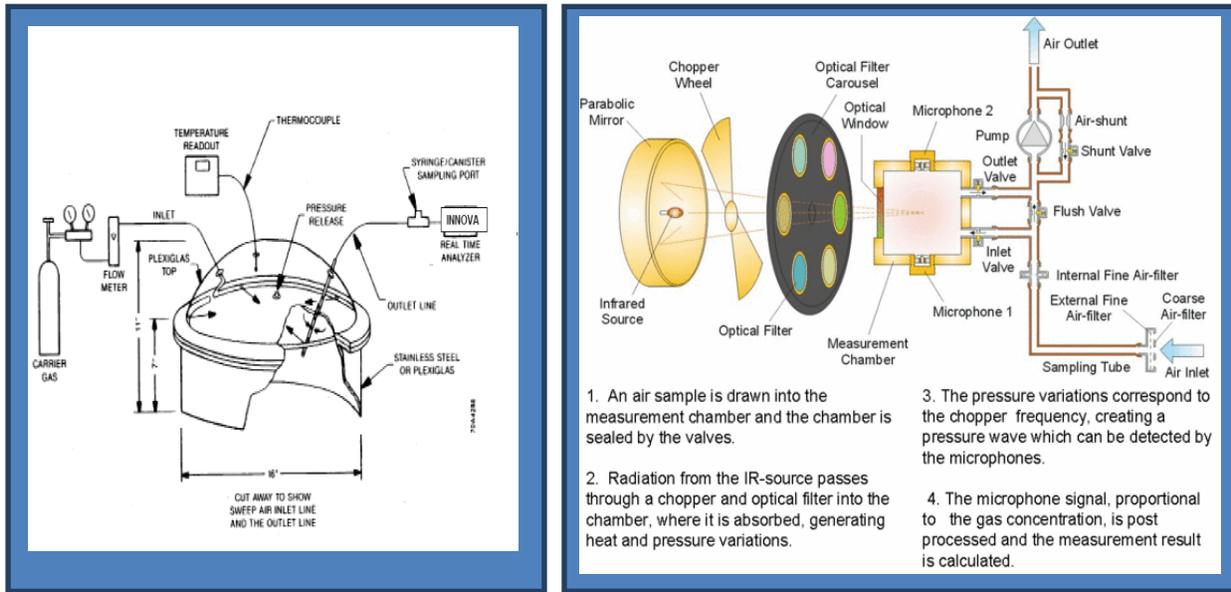


Figure 4: Basic theory and standard operating principles for INNOVA 1412 device.



Figure 5: Photos taken during INNOVA sampling during field preparation at site D.

- Site E- Cotton:** Location: Fresno, CA; Crop/Variety: Cotton/Pima; Soil Type: Sandy Loam, Furrow irrigated; Completely randomized blocks comprising of three N rates = 50,

100 and 150 #N/ac along with treated and non-treated with Nutrisphere[®]. Also included as a control are plots with no fertilizer additions.

Objective: To determine of N₂O fluxes following fertilization and irrigation events for cotton with Urea Ammonium Nitrate (UAN 32) combined with a nitrogenase inhibitor.

Sampling: Flux chamber measurements conducted on beds at four times during the summer.

Results: Samples analyzed (ppm data) using the Gas Chromatograph (G.C).

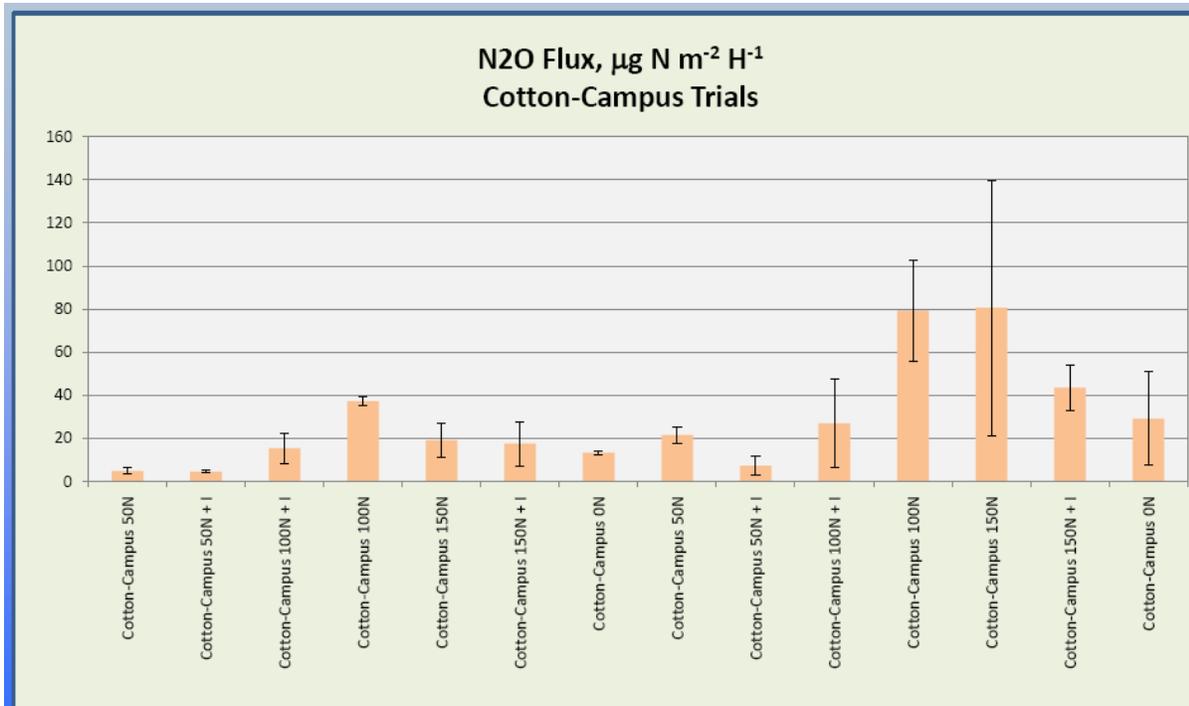


Figure 6: Example of N₂O flux measurements obtained from the various treatments at site E.

Concluding Remarks

Although field measurements have been conducted to date, no scientific conclusions are possible at this time because much of the concentration data still needs to be converted to flux data and statistically analyzed. Based on extensive discussions and re-evaluation of the potential costs associated with conducting sufficient measurements at the research sites, it was concluded that for the off campus measurements, we will limit our experiments to two cotton sites and two corn sites.

The off campus corn and cotton experimental sites in Hanford, the cooperators have agreed to let us collect data during any rotation over next 2 years. At the relatively smaller research plots on the Fresno State campus, we will continue to use these primarily for methodology and protocol development, and sampling under more controlled conditions than what may be possible out on the farmer's fields. At the Fresno State sites, as we improve our expertise with the calibration

and field operation of the INNOVA auto-sampling device, we will compare data obtained with this device to the data from the flux chambers.

Our next phase of work will also focus on preliminary calibration of the Denitrification-Decomposition (DNDC) model for determination of N₂O emissions from corn and cotton subjected irrigation and fertilizer practices at sites A to E. Soil, fertilizer, climatic and irrigation data collected will be used as input parameters for the various algorithms inherent in the DNDC model.

Acknowledgements

In addition to California Department of Food and Agriculture- Fertilizer Research Education Program (CDFA-FREP) grant, matching funds for this research are provided by the California State University - Agricultural Research Initiative (CSU-ARI) program. The field and laboratory work would not have been completed without the dedication of “The Grad Lab” Team: Dr. Denis Bacon, Prasad Yadavali, Bardia Dehghanmanshadi, Navreet Mahal, Janet Robles, Tou Thao, Ben Nakayama, Caio Cesardiaz, Natalio Mendez, Gerardo Orozco and Josue Monroy, among others.

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The Role of Constructed Wetlands in Agriculture

Toby O'Geen Soil Resource Specialist in Cooperative Extension
Dept. of Land, Air and Water Resources
University of California, Davis.

Non-point source pollution (NPS) from agricultural runoff threatens drinking water quality, aquatic habitats, and a variety of other beneficial uses of water resources. Agricultural runoff often contains a suite of water quality contaminants, such as nutrients, pesticides, pathogens, sediment, salts, trace metals and substances contributing to biological oxygen demand. Increasingly, growers that discharge agricultural runoff must comply with water quality regulations and implement management practices to reduce NPS. Constructed and restored wetlands are one of many best management practices that growers can employ to address this problem. This presentation focuses on the ability of constructed and restored wetlands to mitigate a variety of water quality contaminants common to most agricultural landscapes. We found that constructed and restored wetlands remove or retain many water quality contaminants in agricultural runoff if carefully designed and managed. Contaminant removal efficiency generally exceeded 50% for sediment, nitrate, microbial pathogens, particulate phosphorus, hydrophobic pesticides and selected trace elements when wetlands were placed in the correct settings. There are some potentially adverse effects of constructed and restored wetlands that must be considered, including accumulation of mercury and selenium, increased salinity, mosquito habitat, and greenhouse gas emissions. Proper wetland management and design features will be discussed in order to reduce these adverse effects, while optimizing contaminant removal.

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Investigating Potential Benefits of Soil Biochar Amendments

Sanjai J. Parikh, Assistant Professor of Soil Chemistry, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-1265, sjparikh@ucdavis.edu

Fungai N.D. Mukome, Postdoctoral Fellow, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-6216, fmukome@ucdavis.edu

Emma Suddick, Postdoctoral Fellow, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-2136, emmasuddick@ucdavis.edu

Engil I. P. Pereira, Graduate Research Assistant, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-2136, isapereira@ucdavis.edu

Elizabeth Verhoeven, Graduate Research Assistant, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-2136, eeverhoeven@ucdavis.edu

Johan W. Six, Professor of Agroecology, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-1212, jwsix@ucdavis.edu

Introduction

Biochar has received considerable attention as one potential solution to *increase* soil C stocks, soil fertility, and water retention and *decrease* greenhouse gas (GHG) emissions from agricultural soils. Lehmann et al. (2006) estimated biochar could be potentially responsible for the sequestration of 9.5 billion tons of C by 2100. Other studies suggest that biochar applications to soil may help increase N-fixation and decrease N₂O emissions, while retaining native C, improving soil fertility, and increasing water retention in soil (Lehmann, 2007; Rondon et al., 2007; Spokas et al., 2009). This use of biochar as a soil amendment has received increased attention since the discovery of the Terra Preta de Indio soils in the Amazon. These soils received historical applications of charcoal and today have higher organic C and improved soil fertility (Glaser and Woods, 2004; Liang et al., 2006; Sombroek, 1966; Sombroek et al., 1993). Further research of these soils demonstrates decreased CO₂ emissions (61-80% less) per unit C compared to soil with no biochar and identical mineralogy (Liang et al., 2008; Liang et al., 2006). Today, many growers are considering if the use of biochar would be beneficial for them; however, the information to make these decisions is sparse and it often difficult to extrapolate to their unique situation. Biochar is often promoted as a panacea for agricultural and environmental problems, but its actual beneficial results may not be realized due to differences in material characteristics, soil properties, and agricultural systems. To date, the mechanisms for providing multiple ecosystem services and the conditions under which they may be realized are poorly

understood. Our research attempts to address this issue through analysis of biochars from a variety of feedstocks. We are examining the impacts of biochar soil amendments on soil fertility, GHG emissions, C sequestration, microbial communities, and contaminant transport. Our laboratory and field studies highlight the fact that biochar is a variable material and that proper characterization is required to evaluate its potential to provide agronomic and environmental benefits.

Research Highlights

Biochar Characterization. Biochar is a unique material whose characterization is challenging (McLaughlin et al., 1996) and without standard methods of analyses. The Parikh laboratory has modified soil, waste-water, and sludge analysis methods to measure the physical and chemical properties of biochars derived from low temperature wood stock (WF-410° C), high temperature wood stock (WF-510° C) and high temperature walnut shell (WA-900° C). Substantial differences in pH, ash content, CEC and C:N ratios are apparent for biochar from different source materials (Table 1). Preliminary characterization of the biochars using attenuated total reflectance (ATR) Fourier transform infrared (FTIR) and Raman spectroscopies reveal high aromatic contributions to WA900 and increased aliphatic contributions/functionalization of the wood stock biochars.

Table 1. Summary of chemical and physical properties of walnut shell and wood biochars.

| Biochar | Moisture (wt %) | pH _w (1:2) | Ash (wt %) | C (wt %) | N (wt %) | CEC (cmolc/kg) | Surface Area (m ² /g) |
|-----------------------|-----------------|-----------------------|------------|----------|----------|----------------|----------------------------------|
| Walnut Shell (900° C) | 3.1 | 9.7 | 46.6 | 55.3 | 0.47 | 33.4 | 227 |
| Wood Stock (510° C) | 4.4 | 7.3 | 3.1 | 83.9 | 0.36 | 13.2 | 166 |
| Wood Stock (410° C) | 2 | 7.1 | 2.7 | 65.7 | 0.21 | 10.7 | 2.82 |

Biochar-Soil Incubations. Six treatments comprising three biochars and controls of compost, soil and inorganic fertilizer were applied to a Yolo silt loam. Biochars (< 2 mm) were incorporated into soil for an application rate of 10 tons ha⁻¹ and augmented with compost to achieve an application rate of 120 kg N ha⁻¹. Cumulative emissions of CO₂ and N₂O from these treatments under conditions of complete and incomplete denitrification over a period of 30 days are shown in Figure 1. When nitrification was not inhibited, there was no statistical difference in the cumulative CO₂ emissions between the six treatments. When nitrification was inhibited, the cumulative CO₂ emission increased by between 8 to 48%, with the greatest increase occurring in the WA900 treatment and the lowest in the soil only treatment. The cumulative N₂O emissions (Fig. 2b) were not statistically different under either condition and the largest emissions were observed in the compost treatment. Of the biochar treatments, the lowest N₂O emissions arise from the WA900 (walnut shell biochar). Scanning transmission X-ray microscopy (STXM) and synchrotron FTIR (SR-FTIR) analysis of biochar incubated, alone and with Yolo silt loam, reveal changes in the biochar structure resulting from degradation and interactions with soil minerals. For example, preliminary STXM analysis (ALS beamline 5.3.2) of WA900 shows increased aromaticity with aging; as evident by the change in ratio of the aromatic peak (285.3 eV) to the aliphatic peak (287.1 eV) and the presence of a C=O (288.6 eV) after incubation (data not shown).

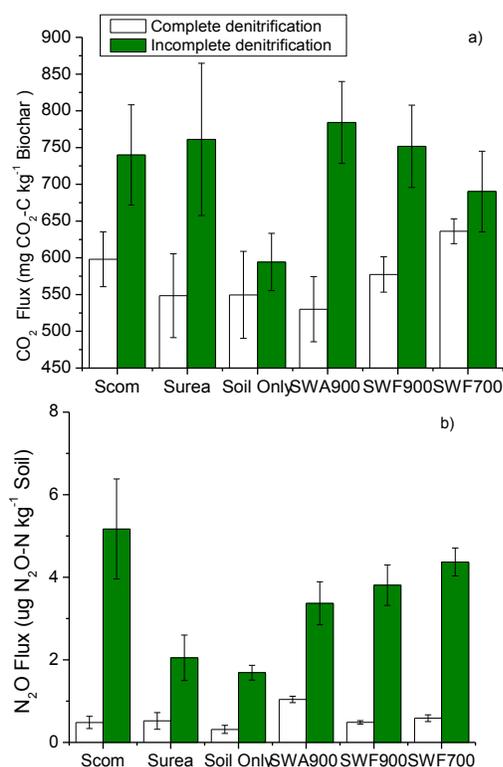


Figure 1. Cumulative evolution of (a) CO₂ and (b) N₂O from a Yolo silt loam soil under six treatments: Compost (Scom), urea (Surea), no biochar (Soil only), walnut shell (SWA900), high (SWF900) and low temperature (SWF700) wood feedstock biochar.

Biochar Interactions with Organic Carbon and Nitrogen and Copper.

To determine the affinity of non-biochar carbon (C) and nitrogen (N) [“native” soil C and N] for various biochars, sorption experiments with water extracts of compost were carried out. The affinity of dissolved C and N for the WA900 is much greater than for the wood stock biochars (Fig. 2a and 2b). Biochars ability to bind heavy metals makes it an interesting material for remediation or filtration of waste material. Sorption experiments with Cu, Pb, Ni, and Cd reveal a high sorption capacity of WA900 for metals; particularly important for the dairy industry is Cu, due to the use of CuSO₄ in footbaths for hoof health (Fig. 2c). The differences in sorption are attributed to aromaticity and/or ash content. These results suggest that walnut shell biochar has potential to address GHG emissions and attenuation of heavy metals in soil.

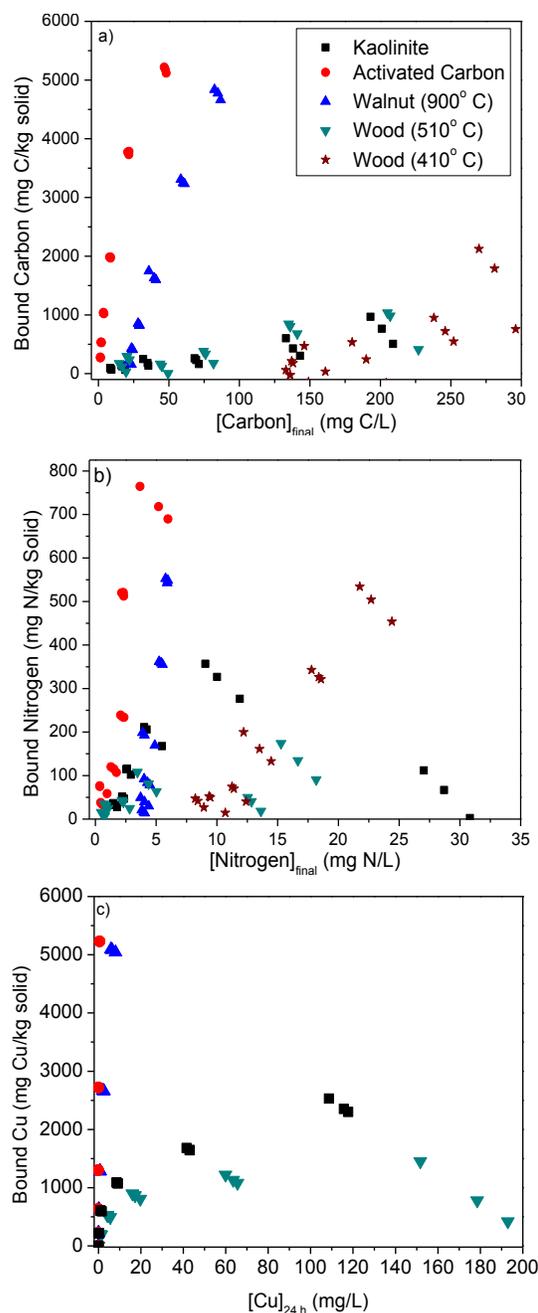


Figure 2. 24 hour Sorption isotherms for a) C, b) N, and c) Cu sorption to biochars, activated carbon, and kaolinite (pH 7, 5 mM NaCl).

Field Trials. In a field trial conducted using WA900 biochar, lettuce was grown in 1 m x 1 m plots and amended with either 5 tons ha⁻¹ biochar, control (no amendment), 5 tons ha⁻¹ compost, or 2.5 tons ha⁻¹ compost plus 2.5 tons ha⁻¹ biochar. N₂O emissions were measured every day during growth until harvest (40 days). Figure 3 shows the first 14 days of measurements where the largest N₂O peak occurred following the initial fertilization and irrigation peak. Emissions of N₂O following the fertilization peak were approximately 41% lower than in the control. It is, however, difficult to pinpoint the exact mechanisms underlying this decreased N₂O flux. One possibility is that the initially observed increased WFPS in the biochar amended soils may have led to a reduction of N₂O to N₂ and therefore the reduced initial N₂O emissions. Later, the WFPS values implicate nitrification as the main process for N₂O emissions and the observed decrease in N₂O emissions might be due to the absorptive properties of the biochar, which can retain NH₄⁺ and thereby reduce nitrification rates and associated N₂O emissions. Furthermore, it has been suggested that biochar can directly adsorb N₂O.

Summary

The data suggest that if benefits from biochar are to be realized that they are not likely to be specific and one-dimensional. Instead biochar may have potential use as a soil amendment which provides a variety of small advantages to enhance overall environmental and agricultural sustainability. Through careful analysis of the impacts from a variety of biochars/soils on agroecosystem services it may be possible to tailor the production of biochar to specific agriculture scenarios based on soil type, water requirements, and crop it may be possible to maximize positive impacts of biochar soil amendments.

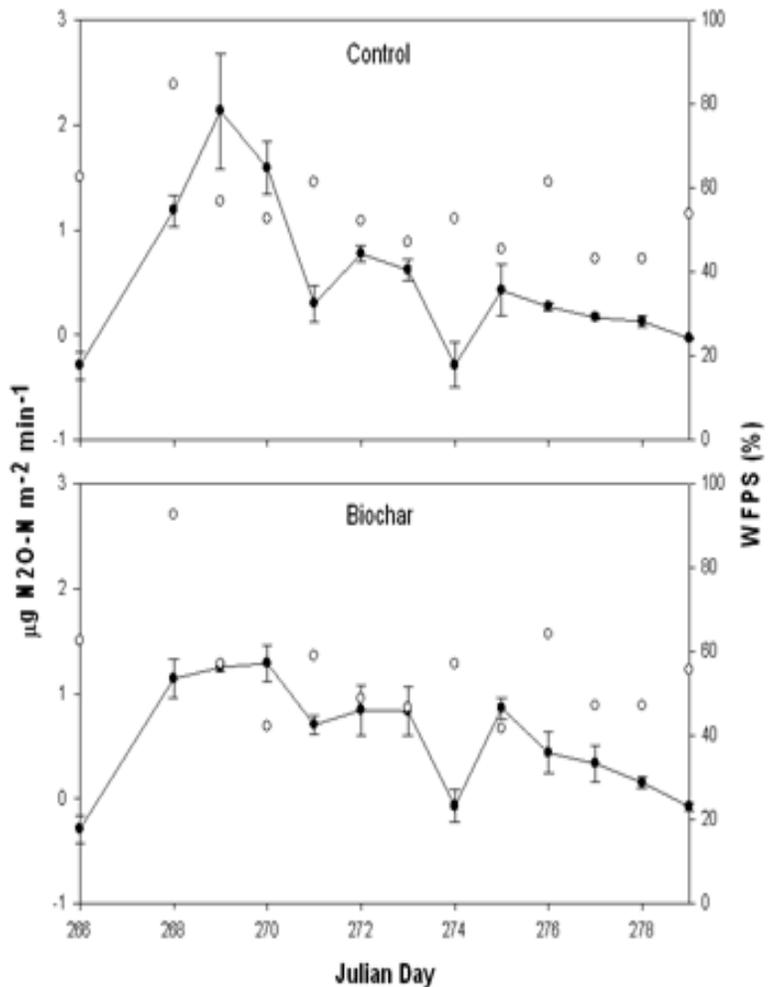


Figure 3. N₂O emissions following 14 days after amending soils with and without biochar (black circles: N₂O emissions; white circle: percent WFPS; error bars are standard error mean, n=5).

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American Society of Agronomy

California Chapter

2012 Poster Abstracts

**Poster Chair:
Rodrigo Krugner**

POSTER SUBMISSION: STUDENT

Title of Paper: **Yield, Fruit Quality and Plant Nutrition of Tomatoes Subjected to Elevated Carbon Dioxide**

Authors: Bardia Dehghanmanshadi, Florence Cassel S., Caio Diaz, Dave Goorahoo, and Shawn Ashkan

Contact Name: Bardia Dehghanmanshadi

Affiliation: California State University, Fresno

Address: 2415 E San Ramon Ave. M/S AS72. Fresno, CA 93740

Telephone: 510-734-0750

Fax: 559-278-7413

E-mail: bardiadm1@mail.fresnostate.edu

ABSTRACT:

Steady increases in atmospheric carbon dioxide (CO₂) have been attributed to global warming and climate variability. Because of the role of CO₂ in photosynthesis and glucose production essential for plant growth, increases in atmospheric CO₂ could potentially lead to greater crop yield. Elevated CO₂ may also influence plant nutrition. The goal of the study was to assess the effects of two different CO₂ levels on tomato yield, fruit quality and plant nutrient content. During summer 2011, tomatoes were grown on a sandy loam soil within sixteen open-top chambers (15ft W x 5ft L x 10ft H) at the California State University-Fresno farm. Half of the chambers received ambient air and the other half were subjected to elevated CO₂ delivered through poly vinyl chloride (PVC) tubes. For the CO₂ enriched plots, mean daily CO₂ levels within the crop canopy ranged from 580ppm to 620 ppm during the 8 hours of application, whereas concentrations in the ambient plots averaged 390 ppm. Subsurface drip irrigation was used to apply water at rates equivalent to 100% ET and 80% ET based on California Irrigation Management Information System (CIMIS) data. There was no significant difference ($\alpha \leq 0.10$) in the yield of red and green tomatoes, and in the incidence of blossom end rot. However, CO₂ and irrigation rate had a significant effect ($\alpha \leq 0.10$) on the yield of breaker tomatoes, with the greatest amount of breakers occurring within the plots subjected to elevated CO₂ and 100% ET. Elevated CO₂ did not have any significant effect on the tomato Brix indices. Leaf N and P content were significantly affected with the highest levels measured in the Ambient CO₂-80% ET treatment. There was no significant difference in leaf K content at the end of season. These results are a major contribution to the overall goal of our ongoing research aimed at evaluating productivity, quality and water use efficiency for vegetable crops subjected to elevated CO₂ levels.

POSTER SUBMISSION: STUDENT

Title of Paper: **Development and Optimization of the Steam Auger for Management of Almond Replant Disease**

Authors: Bobby Johnson¹, Brad Hanson¹, David Doll³, Greg Browne², and Steve Fennimore¹

Contact Name: Bobby Johnson

Affiliation: ¹Department of Plant Sciences, University of California, Davis; ²USDA ARS, Crops Pathology and Genetics Unit, Davis, CA; and ³University of California Cooperative Extension, Merced County, CA

Address: 731 Elmwood, Davis, CA 95616

Telephone: 417-861-5379

Fax:

E-mail: bobjohns@ucdavis.edu

ABSTRACT:

Replant disease (RD), caused by a host specific soil-borne microbial complex, can be a serious concern when planting second and third generation orchards. With the phase out of methyl bromide orchard fumigation has shifted towards other fumigants such as 1,3-dichloropropene and chloropicrin. While these fumigants often provide acceptable control of RD, all soil fumigants are facing increased regulatory restrictions and are not available in every situation. One non-fumigant approach to managing RD is to combine the benefits of limited area fumigation treatments (spot treatments) with thermal soil disinfestation using steam applied with an auger-based injection unit. The overall goal of this project is to develop and optimize steam spot treatments for control of almond replant disease without the use of soil fumigants. Several field trials were initiated between 2009 and 2011, on different soil types to allow comparisons among steam disinfestation, soil disturbance alone, shank applied fumigants, and several other non-fumigant treatments in management of RD. Although this research is at an early stage, our early data suggests that steam disinfestation is not likely to provide the same level of RD management as chemical fumigants. However, tree site steaming or other non-fumigant approaches being tested may be useful to almond growers unable or unwilling to use soil fumigants. Because preplant fumigation can impact orchard establishment and early growth, efficacy and viability of these non-fumigant approaches to manage RD will be monitored for at least two more years before final conclusions can be made.

POSTER SUBMISSION: STUDENT

Title of Paper: **Can Biochar Reduce Mobility of Pharmaceuticals in Biosolid Amended Soils?**
Authors: Daniel A. Bair, Thomas M. Young, and Sanjai J. Parikh
Contact Name: Daniel A. Bair
Affiliation: University of California, Davis
Address: 3233 PES Building, One Shields Ave, Davis, CA 95616
Telephone: 530-752-6216
Fax: 530-752-1552
E-mail: dabair@ucdavis.edu

ABSTRACT:

Municipal wastewater treatment plants have been identified as major sources for pharmaceutical release into the environment. Land application of biosolids can transfer pharmaceutical compounds and their degradation products to the soil environment, allowing for potential bioavailability. Environmental exposure of these contaminants could adversely affect wildlife, lead to the disruption of microbial communities, detrimentally impact human health through long-term exposure to trace levels of pharmaceuticals, and cause the proliferation of antibiotic resistant bacteria. Biochar, a co-product of biofuel production, has potential to stabilize biosolid C, N, and P in soil, increase soil fertility and crop yield, and attenuate heavy metals, agrochemicals, and pharmaceuticals. Due to the chemical composition of biochar (high aromaticity, and hydrophobic nature) they are potentially favorable sorbents for pharmaceuticals and other contaminants. The use of biochar as a co-amendment with biosolids can provide important benefits to agroecosystems by reducing contaminant mobility and improving soil fertility. We examined the sorption of ciprofloxacin, a fluoroquinolone antibiotic used in human medicine, to soil (Yolo silt loam), kaolinite, biochar (wood feedstock and walnut shell), activated carbon, biosolids and a soil/biochar/biosolid mixture. Sorption studies were conducted via laboratory batch experiments and ciprofloxacin was analyzed using LC-MS/MS. Ciprofloxacin exhibited significant sorption to activated carbon, walnut shell biochar and the Yolo silt loam soil while both kaolinite and the wood feedstock biochar had much lower ciprofloxacin sorption.

POSTER SUBMISSION: STUDENT

Title of Paper: **Yield of a Bell Pepper Cultivar Subjected to Regulated Deficit Irrigation and Various Nitrogen Levels**
Authors: David Scheidt, Dave Goorahoo, and Florence Cassel S.
Contact Name: David Scheidt
Affiliation: California State University, Fresno
Address: 2415 E San Ramon Ave. M/S AS72. Fresno, CA 93740
Telephone: 559-367-7080
Fax: 559-278-7413
E-mail: david5699@mail.fresnostate.edu

ABSTRACT:

Bell pepper cultivar *Pismo*, is a determinate blocky bell pepper cultivar with an extensive crop canopy and extra large fruit size. *Pismo* has shown promising yields in pre-commercial production. However, there is a need to test *Pismo* to determine the optimum water use efficiency. The purpose of the current study was to examine three irrigation regimes and three levels of nitrogen to evaluate the yield of *Pismo* under regulated deficit irrigation (RDI). The experiment used a Randomized Complete Block Design split plot with irrigation being the main plot and fertilizer being the sub plot. There were four irrigation treatments, three nitrogen treatments and six replications using pots filled with sandy-loam soil at the ornamental horticulture unit at California State University, Fresno. Water treatment 1 was irrigated at 100% soil capacity from plant establishment until harvest. Treatment 2 was irrigated at 75% field from the stage of after plant establishment until first fruit set. Treatment 3 was irrigated at 75% soil capacity from first fruit set until harvest. Treatment 4 was irrigated at 75% soil capacity from plant establishment until harvest. The crop was irrigated as needed to bring the soil to the water capacity of the treatment. The experiment was transplanted on August 2nd, 2010 with the first harvest on October 18th, 2011. Yield and growth characteristics data are currently being analyzed and would be presented at the poster presentation.

POSTER SUBMISSION: STUDENT

Title of Paper: **The Relationship Between New Precision Agriculture Soil Mapping Techniques and Soil, Plant, Water Relations in Pistachio**
Authors: Kevin Brooks, Scott Jorgensen, and Bruce Roberts
Contact Name: Kevin Brooks
Affiliation: California State University, Fresno. Department of Plant Science, M/S
Address: 6258 North 3rd. St. Fresno, CA 93710
Telephone: 559-908-6686
Fax: 559-935-5609
E-mail: brooksi360@mail.fresnostate.edu

ABSTRACT:

Annual estimates of 34 million acre feet of water are used to irrigate 9.6 million acres of California agriculture. Climatic conditions such as drought often cause extreme shortages and irregularity in water supply to the western San Joaquin Valley (SJV). The uncertainty of water supply poses certain irrigation and plant/soil/water challenges to the established 187,000 acres of pistachio trees. Consequently, growers have had to adapt and become more efficient with water. As a result, adoption of direct and indirect monitoring techniques measuring plant water status in combination with new precision soil mapping techniques have been utilized to conserve water and increase water use efficiency. These precision soil mapping techniques provide high resolution of descriptive physical/chemical soil characteristics that influence soil and plant water relations and may create a new management strategies for irrigating pistachio trees. A field study was initiated to study the following objectives: 1) map and isolate key areas within the field that differ in soil texture, water holding capacity and hydraulic conductivity, 2) monitor plant and soil water status and evaluate the effects the differing soil textures have on yield. Data analysis demonstrated significant differences in plant water status and yield data by the differing soil textures and soil water conditions. Our secondary objective was to determine the potential water savings and production benefits that can be achieved when combining precision technologies with accurate plant and soil water status monitoring. Furthermore, establish a descriptive analysis of tools used to monitor plant water stress and determine whether future irrigation systems could possibly be governed by soil characteristics to maximize application and water use efficiency.

POSTER SUBMISSION: STUDENT

Title of Paper: **Optimizing *in vitro* Propagation of Douglas Fir (*Pseudotsuga menziesii*) for Use in Pacific Northwest Timber Industry Reforestation Efforts**

Authors: Kevin Flynn, Sheri Melkonian, David Moreno, and John T. Bushoven

Contact Name: John T. Bushoven

Affiliation: Plant Tissue Culture Laboratory, Department of Plant Science, California State University, Fresno

Address: 2415 East San Ramon Avenue, M/S AS72, Fresno CA, 93740

Telephone: 559-278-7391

Fax:

E-mail: jbushoven@csufresno.edu

ABSTRACT:

Douglas Fir (*Pseudotsuga menziesii*) is one of the most important timber species in the United States, and although propagation of this species occurs naturally through seed, the inconsistency in cone production and a 10-15 year life-cycle prohibits the large-scale use of seed as a propagule source. Attempts to propagate this species through vegetative methods have not been widely successful primarily due to the rapid deterioration of propagules prior to rooting. To remedy this, much effort has been focused on the use of *in vitro* culture as a method for propagating these species. To date, thin-cell-culture, embryo-culture, somatic-embryogenesis and direct-organogenesis from cotyledon-, or hypocotyl-derived calli have been utilized with varying degrees of success. The objective of this project was to 1) conduct side-by-side evaluations of the efficacy of these existing methods and 2) to optimize acclimatization of these *in vitro* derived cultures to greenhouse and nursery environments. A preliminary evaluation of seed dormancy was conducted via *in vitro* culture of scarified, stratified seed, and several degrees of embryo excision in which intact embryos were microscopically dissected from surrounding seed coat and endosperm. Seed were initially surface sterilization with 20% NaOCl, 75% EtOH and cultured on standard Quoirin and Lepoivres media supplemented with 3% w/v sucrose and solidified with 0.65% TC agar and maintained in a growth room under 16/8h (day/night), 50 $\mu\text{M m}^{-2} \text{s}^{-1}$ at 25 °C. *In vitro* culture acclimatization was evaluated with the use of vermiculite filled 0.5 mm polypropylene bags modified with varying additions of KOH to absorb CO₂ or KMnO₄ pellets to oxidize C₂H₄. The results of this study increased our understanding of the factors limiting clonal propagation of *P. menziesii*.

POSTER SUBMISSION: STUDENT

Title of Paper: **Free Potassium Fertilizer? Potential Problems with Land Applications of Winery Wastewater**

Authors: Maya C. Buelow, Kim Mosse, G. Stuart Pettygrove, Kerri L. Steenwerth, and Sanjai J. Parikh

Contact Name: Maya C. Buelow

Affiliation: University of California, Davis

Address: Department of Land, Air & Water Resources, One Shields Avenue, Davis, CA 95616-8627

Telephone: 530-752-1130

Fax: 530-752-1552

E-mail: mayab4@gmail.com

ABSTRACT:

The increasing scarcity of water and tighter regulations for discharge make onsite wastewater reuse an attractive prospect for the California wine industry. For this study, background surveys were conducted to assess winery wastewater treatment methods and volumes, as well as types and amounts of cleaning agents used. Monthly winery wastewater samples were collected to represent water leaving the winery, before and after treatment. Generally, EC of the effluent of wineries of 1mil.gal/yr production or more has been above 1000 $\mu\text{S}/\text{cm}$, whereas wineries producing less than 1mil.gal/yr have averaged closer to 400 $\mu\text{S}/\text{cm}$. Sodium absorption ratio (SAR) and potassium absorption ratio (PAR) of the wastewater were also determined. These baseline data informed decisions about the composition of the leaching solutions applied to soil column studies investigating the effects of Na-rich and K-rich solutions on saturated hydraulic conductivity (K_{sat}). The impact of both current (Na- and P- rich water) and emerging (increasingly K-rich) wastewater applications on soil physical and chemical properties is not well understood. Irrigation with treated wastewater has potential for both beneficial and detrimental consequences for soil properties. Soil mineralogy is hypothesized to exhibit a large influence on the effect of K on structural stability and K_{sat} of soils. To examine this relationship, these experiments are being conducted with three vineyard soils of diverse mineralogy from the Napa and Lodi region. The SAR and PAR will be calculated to make predictions about expected reductions in K_{sat} . These calculations will be compared to predictions made using the monovalent cation ratio (MCAR), and the recently published 'cation ratio of structural stability' (CROSS), equations to examine the reliability of these four equations to predict reductions in K_{sat} .

POSTER SUBMISSION: STUDENT

Title of Paper: **Response of Yield and Quality to Plant Density and Nitrogen Fertilizer Levels in Sweet Corn**
Authors: Nathalia Moretti, Sharon Benes, and Ganesan Srinivasan
Contact Name: Nathalia Moretti
Affiliation: Jordan College of Agricultural Sciences and Technology, California State University, Fresno.
Address: 2385 E Barstow MS AG85, Fresno, CA
Telephone: 559-278-5193
Fax:
E-mail: nmourad@mail.fresnostate.edu

ABSTRACT:

California is the second largest state in sweet corn fresh market production, accounting for 16% of the country's total production. Nitrogen (N) management is one of the biggest challenges in vegetable production. It has a great contribution to plant growth and yield increase but it is also easily lost causing environmental problems when over applied. On the other hand, optimum plant density (PD) is necessary to achieve maximum yield of a specific variety in an environment. This study was conducted in 2010 with the hybrid Mirai 148Y and in 2011 with the hybrid Vision. Three N levels (165, 225 and 280kg/ha) and three plant densities (60k, 75k and 90k seeds/ha) were tested with Mirai hybrid in 2010. In 2011, an additional N treatment (112kg N/ha) and a PD treatment (50k seeds/ha) were included. The two hybrids had different responses to N and PD. For Mirai hybrid, highest yield was achieved with 60k seeds/ha and 225kg N/ha, while Vision performed better with 75k seeds/ha and 165kg N/ha.

POSTER SUBMISSION: STUDENT

Title of Paper: **Impact of Common Pesticides on Beneficial Arthropods in the Almond Orchard**
Authors: Nathan Cannell, Andrew B. Lawson, and Kent M. Daane
Contact Name: Nathan Cannell
Affiliation: California State University, Fresno
Address: 18588 E. Adams Ave. Reedley, CA. 93654
Telephone: 559-301-2209
Fax:
E-mail: nccannell@mail.fresnostate.edu

ABSTRACT:

Successful integrated pest management programs are ones that anticipate and avoid problems by using management methods that are least disruptive to the system. The current economics of almond production is encouraging some growers to utilize more chemically intensive management practices as the primary means of pest control in the almond system in order to maximize economic gains. It is essential to fully understand the ecological implications of using these materials, and several new acaricides boasting “pest specificity” needs to be examined in order to assess their true impact upon several beneficial arthropods found in the system. It is the intent of this study to examine the lethal and sublethal effects of the popular acaricides abamectin (Agrimek), spiroadclofen (Envidor), hexythiazox (Onager) and etoxazole (Zeal) upon the beneficial arthropods *Copidosoma plethorica* (Caltagirone), *Goniozus legneri* (Gordh), *Chrysoperla carnea* (Stephens), *Scolothrips sexmaculatus* (Pergande), *Galendromus occidentalis* (Nesbitt) and an *Aphytis* sp. via an indirect residual contact bioassay.

POSTER SUBMISSION: STUDENT

Title of Paper: **Yield and Forage Quality of Elephant Grass (*Pennisetum sp.*) Irrigated with Secondary Treated Municipal Waste Water and Dairy Effluent**

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

Contact Name: Prasad Yadavali

Affiliation: California State University, Fresno

Address: 2415 E San Ramon Ave. M/S AS72. Fresno, CA 93740.

Telephone: 559-289-9388

Fax: 559-278-6033

E-mail: prasadylv@mail.fresnostate.edu

ABSTRACT:

In California, waste water treatment plants and dairies are potential sources of nitrate (NO₃) contamination in groundwater. One of the NO₃ remediation techniques is to grow nitrogen (N) scavenging crops, commonly known as “bio-filters”. In this study yield and forage quality was evaluated for Elephant grass (*Pennisetum sp.*) and Sudan grass (*Sorghum bicolor*) in soils irrigated with secondary treated municipal waste water (MW) and dairy effluent (DE). Greenhouse experiments were conducted in 5 gallon pots in a completely randomized design (CRD), with three irrigation rates (0, 50 and 100 percent) of effluent, replicated four times. The forages were harvested at 8, 10 and 12 weeks. At any given harvest date N rates did not significantly affect grass yields. The average biomass for the grasses harvested at 8 and 10 weeks were generally higher for plants irrigated with the DE than those irrigated with the MW. By the 12th week, similar yields were obtained for each grass regardless of the water source. Highest crude protein (CP) and total digestible nutrients (TDN) were detected in grasses harvested at 8 weeks. The exception was the EG treated with MW, which had its greatest CP and TDN values at 12 weeks. Nitrate content of grasses increased with harvest dates. Grasses irrigated with DE exhibited their greatest NO₃ levels earlier (at 8 weeks) than those receiving MW. Grasses receiving MW accumulated as much as five times more NO₃ than those treated with DE. Findings from this current trial concur with those from our previous studies, which identified elephant grass as a highly nutritious forage crop with the ability to readily take up N from soils subjected to high rates of N fertilization.

POSTER SUBMISSION: STUDENT

Title of Paper: **Determining the Abundance of Pine Bluegrass on the San Joaquin Experimental Range – Part II**
Authors: Sheri Melkonian, Teri Lee, and Bruce Roberts
Contact Name:
Affiliation: California State University, Fresno. Department of Plant Science.
Address: 2415 East San Ramon Avenue M/S AS72, Fresno, CA 93710
Telephone: 559-278-1758
Fax: 559-278-7413
E-mail: sherilee@mail.fresnostate.edu

ABSTRACT:

Pine bluegrass (*Poa secunda* Turb.) is a native perennial bunchgrass found in the predominantly annual grass system of the San Joaquin Experimental Range (SJER). In 1958, this remnant native grass was classified as “common in abundance” across the SJER (Buttery and Green 1958). Since the last reported survey, SJER pastures have experienced a range of controlled cattle grazing intensities. Our hypothesis is that different grazing practices have affected the abundance of this native bunchgrass. The aim of this project is to reevaluate the abundance of this native grass after 53 years of different grazing management protocols. Also to establish a species base line to accurately monitor future change. As part of the Range Ecology and Management course at Fresno State, this annual activity introduces students to field monitoring and grass species identification. Field monitoring techniques will use line transects to evaluate the abundance of pine bluegrass in different pastures of the SJER where different grazing practices and intensities have been used. Pastures will be assessed for species presence and numbers to compare with previously reported surveys. Other sampling techniques will be used to compare monitoring results. Findings will be recorded using GPS positions and mapped on satellite images of the different pastures. Students will gain field experience in range surveys and GPS usage. In time, the data will be used to correlate the abundance of Pine bluegrass with different grazing histories. Students will be involved in developing grazing practices that conserve the abundance of Pine bluegrass in California’s oak grasslands.

POSTER SUBMISSION: STUDENT

Title of Paper: **Effect of Nitrogen Fertilization Practices on Wheat Protein Content in the San Joaquin Valley 2011-2012**

Authors: Steve Wright, Steve Orloff, Bob Huttmacher, Gerardo Banuelos, Katie Wilson, and Sonia Rios

Contact Name: Sonia Rios

Affiliation: University of California Cooperative Extension & Cal Poly Pomona

Address: 4437 S. Laspina St. Tulare, CA 93274-9537

Telephone: 559-360-5920

Fax: 559-685-3315

E-mail: Sonia_rios1@yahoo.com

ABSTRACT:

Growers seek both high yield and high protein content to improve the profitability of wheat production. This can be difficult to achieve especially with many of the newer higher yielding wheat varieties. University of California studies in the 1980's demonstrated late-season N applications conducted in the San Joaquin Valley increased grain protein content by 0.5 to 2 percent depending on rate and timing. This work was done with Yecora Rojo (already a high nitrogen accumulating wheat variety). Up until last year Joaquin a HR wheat was planted on significant amounts of acreage largely because of its yield, earliness, but mostly because it was easier to reach higher protein levels than other available HR wheats. Research is needed to evaluate the effectiveness of this practice on a range of newer varieties to quantify the level of nitrogen and proper timing needed to achieve both high protein and yields. To accomplish this research objective a study is proposed in the southern San Joaquin Valley. This study should complement a similar study with similar treatments planned to be conducted in Siskiyou County with different varieties so that we have a range of varieties, seasonal variation, and at least 2 years of data. This study is a follow up to repeat what was done last year. Two major commercial hard red and one hard white wheat varieties will be evaluated to determine their yield and protein content with and without late-season N applications.

POSTER SUBMISSION: STUDENT

Title of Paper: **Effect of Vermicompost Tea and Irrigation Rates on Soil Chemical Properties and on Growth of Bell Peppers**
Authors: Tari Lee Frigulti, Sherri Melkonian, Janet Robles, Prasad Yadavali, and Dave Goorahoo
Contact Name: Tari Lee Frigulti
Affiliation: Plant Science Department. California State University, Fresno
Address: 2415 E. San Ramon Ave. M/S AS72, Fresno, CA 93740
Telephone: 559-334-7729
Fax: 559-278-7413
E-mail: tleaf@mail.fresnostate.edu

ABSTRACT:

Vermicompost is the product derived from the breakdown of organic waste by the action of earthworms. The aqueous extract from vermicompost is commonly referred to as “vermicompost tea” (VCT). In this study the effects of VCT concentrations and reduced water application rates were evaluated on soil pH, nitrate (NO₃) and electrical conductivity (EC), and on the growth of bell peppers (*Capsicum annuum* L.). A greenhouse study was conducted using 2.5-gallon pots in a completely randomized design, replicated four times, with two VCT concentrations (full and half strength) and three irrigation rates (IR) applied at 100%, 80% and 60% of ET_c. Bell peppers were established as transplants, and IR and VCT applications were based on Hydrosense™ soil moisture monitoring and visual observations of leaf turgidity or wilting. Between 90 to 120 days after transplanting (DAT) peppers were harvested and any remaining blossoms and flowers were counted. At 120 DAT, plant and root biomass were determined and soil samples were analyzed for pH, NO₃ and EC. The VCT and IR had no significant effects on root dry weight, pepper yield, soil pH, NO₃ and EC. However, there was a significant difference in plant dry weight, with average weights ranging from 11.6 grams for the 50% VCT / 100% IR treatment to 23.8 grams for 0% VCT /100% IR treatment. The counts for the treatments with 0% VCT, 50% VCT and 100% VCT were 27, 29 and 68 blossoms and flowers respectively. Generally, plants that received the 0% VCT had the greatest biomass, while plants that received 100% VCT had the most blossoms and flowers. Pepper yield was poor due to an unexpected mite infestation.

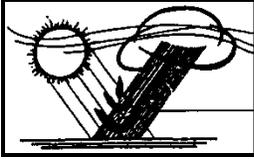
Funding for this project was provided by CSU 2010-2011 Undergraduate Research Grant administered by Office of Undergraduate Studies.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: **Assessment of Nutrient Availability from Organic Nutrient Sources on Organic Vegetable Production in California**
Authors: Sajeemas Pasakdee, Javier Solis, Dave Goorahoo, and Ganesan Srinivasan
Contact Name: Sajeemas Pasakdee
Affiliation: Center for Irrigation Technology (CIT), California State University, Fresno
Address: 5370 N. Chestnut Ave. M/S OF 18, Fresno, CA 93740
Telephone: 559-278-2828
Fax: 559-278-6033
E-mail: spasakdee@csufresno.edu

ABSTRACT:

Organic farming is one of the fastest growing sectors of agriculture. Information on the effect of various soil fertility inputs, i.e., compost, cover crop, organic fertilization and their interactions on short-term and long-term crop productivity and soil nutrient will benefit growers' management decision to improve their on-farm nutrient use efficiency. We evaluated three soil fertility inputs from various organic nutrient sources on an annual organic vegetable production in California's Central Valley. The three treatments were (1) compost only, (2) compost mixed with pelletized organic fertilizer, and (3) cover crop only in four completely randomized blocks. We planted *Cucurbita pepo* (Italian zucchini) after applications of treatment no. 1 & 2 while the cover crop treatment was planted with *Vigna unguiculata* (cowpea) in Spring 2011. The fall planting without additional fertility inputs to all treatments were *Brassica juncea* (L.) Czern. cv. Florida broadleaf. We assessed seasonal changes of soil NO₃-N, PO₄-P, K, plant tissue N, crop N uptake, and yield. The results of this study will be discussed.



**California Chapter – American Society of Agronomy
2010 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.

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: _____
