



American Society of Agronomy

California Chapter

Co-sponsored by the California Plant Health Association

2013

CONFERENCE

PROCEEDINGS

***KEEPING CALIFORNIA
AGRICULTURE PROACTIVE AND
INNOVATIVE***

February 7 & 8, 2013

**Marriott Hotel at the Convention Center
Visalia, CA**

BREAK SPONSORS

Thank You



Thank you to the following sponsors for support of the
2013 California Plant and Soil Conference



2013 CALIFORNIA PLANT AND SOIL CONFERENCE
KEEPING CALIFORNIA AGRICULTURE PROACTIVE AND INNOVATIVE
THURSDAY, FEBRUARY 7, 2013

9:50 **General Session Introduction** – Session Chair & Chapter President – **Allan Fulton**, UC Cooperative Extension
 10:00 Small Steps or Quantum Leaps: How will California Horticulture Maintain its Competitiveness? **Nick Dokoozlian**, E & J Gallo Winery

CONCURRENT SESSIONS (AM)

- | | |
|---|--|
| <p>I. Pest Management</p> <p>10:55 Introduction – Session Chairs: Rodrigo Krugner-, USDA-ARS, Parlier, Anil Shrestha- CSU Fresno, Matt Fossen, DPR, Sacramento.</p> <p>11:00 Tomato Spotted Wilt Virus Management Plan in Central California Processing Tomatoes, Thomas Turini, Cooperative Extension Fresno County.</p> <p>11:25 Integrated Approach to Controlling Serious Burrowing Pests, Roger A. Baldwin, U.C. Kearney Agriculture Research & Extension Center.</p> <p>11:50 Efficacy of Fluopyram for Controlling Hull Rot and Leaf Spot Diseases in Almonds, J. Alfonso Cabrera, Western Field Tech. Station, Bayer Crop Science.</p> | <p>II. Innovative Dairy Technologies</p> <p>10:55 Introduction – Session Chairs: Dave Goorahoo- CSU Fresno, and Danyal Kasapligil, Dellavalle. Laboratory, Fresno, CA.</p> <p>11:00 Quantifying and Modeling Greenhouse Gases at Dairies, Alam Hasson, CSU Fresno.</p> <p>11:25 Minimum Tillage & Soil Conservation Management Practices for Forages in Dairy operations, Dino Giacomazzei, Dairy Farmer & UC Conservation Agriculture Systems Innovation (CASI).</p> <p>11:50 Soil and Water Monitoring for Comprehensive Nutrient Management Plans, Ben Nydam, Dellavalle Laboratory, Fresno, CA.</p> |
|---|--|

12:15 PM LUNCH – Opportunity to Network with Colleagues and Friends

CONCURRENT SESSIONS (PM)

- | | |
|---|---|
| <p>III. Plant Nutrition</p> <p>1:30 Introduction – Session Chairs: Rich Rosecrance, CSU-Chico, and Mary Bianchi, UCCE, SLO.</p> <p>1:35 Tracking Nutrient Budget Trends in the West using NuGIS, Rob Mikkelsen, Western North America IPNI.</p> <p>2:00 Best Management Nutrient Practices for Nut Crops, Bob Beede, U.C. Cooperative Extension, Kings County.</p> <p>2:25 Nitrogen Transformations, 15N Assimilation and Recovery for California Almond, Daniel L Schellenberg UC- Davis.</p> | <p>IV. Crop Production and Mechanization</p> <p>1:30 Introduction – Session Chairs: Bob Hutmacher, UC Davis, and Warren Hutchings, Innovative Ag Services.</p> <p>1:35 New Approaches to Olive Production Systems and Harvest Operations, Louise Ferguson, UC Kearney Agriculture Research & Extension Center.</p> <p>2:00 Mechanical Harvest Research for Wine Grapes, Kaan Kurtural, CSU- Fresno.</p> <p>2:25 Testing for Soil N Mineralization Rate, Joe Mullinax, Denele Laboratories.</p> |
|---|---|

2:50 – 3:00PM: Discussion
3:00-3:20PM: Break

2:50 – 3:00PM: Discussion
3:00-3:20PM: Break

4:35 – 4:45PM: Discussion

4:35 – 4:45PM: Discussion

5:00ADJOURN to a Wine and Cheese Reception in the Poster Room. A complimentary drink coupon is included with your registration

2013 CALIFORNIA PLANT AND SOIL CONFERENCE
KEEPING CALIFORNIA AGRICULTURE PROACTIVE AND INNOVATIVE
FRIDAY, FEBRUARY 8, 2013

CONCURRENT SESSIONS (AM)

- | | |
|--|---|
| <p>V. Water Management
8:30 Introduction – Session Chairs: Florence Cassel-Sharma, CSU Fresno, and Allan Fulton, UC Cooperative Extension, Tehama County.</p> <p>8:35 Standardized Testing of Soil Moisture Sensors and ET Controllers, Diganta Adhikari, Center for Irrigation Technology, CSU- Fresno.</p> <p>9:00 Integrating Soil Moisture Monitoring into Irrigation Management, Bruce Ferri, Almond Grower and CSU- Fresno.</p> <p>9:25 “CropManage”- A Web-based Irrigation and Nitrogen Management Tool, Michael Cahn, UC Cooperative Extension, Monterey County.</p> <p style="text-align:center">9:50 – 10:00 am Discussion
10:00-10:15 Break</p> <p>10:20 Designing Irrigation Systems to Manage Variable Soils, Brian Bassett, H₂O~ Optimizer, Fresno.</p> <p>10:45 Water Management Strategies for Table Grapes, Jim Ayars, USDA ARS Water Management Laboratory.</p> <p>11:10 Regional Assessment of Vineyard Water Use in the Central Coast, Mark Battany, UC Cooperative Extension, SLO County.</p> | <p>VI. Soil Salinity & Managing Soil Quality
8:30 Introduction – Session Chairs: Steve Grattan and Toby O’Geen, UC Davis.</p> <p>8:35 New Advancements in SoilWeb: On demand soils Information with Mobile Devices, Toby O’Geen, UC Davis.</p> <p>9:00 Herding Nitrogen, Herding Cats: Recent Improvements, Continuing Challenges, and Possible Solutions for California agriculture Stu Pettygrove, UC Davis.</p> <p>9:25 Beyond Conservation Tillage: Merging Technologies for Greater Efficiencies, Jeff Mitchell, UC Davis.</p> <p style="text-align:center">9:50 – 10:00 am Discussion
10:00-10:15 Break</p> <p>10:20 Reducing Sediment Loss and Protecting Water Quality in Coastal Vegetables, Michael Cahn, UC Cooperative Extension, Monterey County Water.</p> <p>10:45 Quality Criteria for Use of Saline/Degraded Water for Irrigation, Donald Suarez, USDA, ARS Salinity Laboratory.</p> <p>11:10 Salinity and Drainage Management in the SJV: Where Are We Today? Sharon Benes, CSU-Fresno.</p> |
|--|---|
- 11:35 – 11:50 AM: Discussion**

11:50 AM: Assemble for Annual Chapter Meeting and Luncheon, Conference Adjourned

12:00- 1:30 PM: ANNUAL CHAPTER BUSINESS MEETING LUNCHEON
Presentation of Honorees, Scholarship awards, and Election of officers

**Remember to fill out the survey.
See you next year!**

THANK YOU!

To download additional copied of the proceedings or learn about the activities of the California Chapter of the American Society of Agronomy, visit the Chapter’s web site at:

<http://calasa.ucdavis.edu>

Table of Contents

Past Presidents	1
Past Honorees	2
2012 Chapter Board Members	3
Minutes – CA Chapter ASA 2011 Business Meeting	4
2013 Honorees	7
2013 Scholarship Recipient Essays	12
General Session	14
Small Steps or Quantum Leaps: How will California Horticulture Maintain its Competitiveness? Nick Dokoozlian, E&J Gallo Winery	15
Session I. Pest Management	16
Research-Based <i>Tomato spotted wilt virus</i> Management Plan in Central California Processing Tomatoes T. A. Turini, University of California, Agriculture and Natural Resources.....	17
Managing Burrowing Pests in California Agriculture R.A. Baldwin, UC Kearney Ag Research & Extension Center	23
Efficacy of Fluopyram on <i>Monilinia spp.</i> , <i>Rhizopus stolonifer</i> and carboxamide resistant <i>Alternaria alternata</i> J. Alfonso Cabrera, Western Field Technology Station, Bayer Crop Science	29
Session II. Innovative Dairy Technologies	34
Greenhouse Gas Measurements at a Central California Dairy A. Hasson, California State University, Fresno	35
A Systems Approach to Conservation Tillage of Forage Crops: A California Dairyman’s Perspective D. Giacomazzi, Dairy Farmer & UC Conservation Agriculture Systems Innovation	36
Manure Management for Solid and Liquid Manure Nitrogen Application B. Nydam, Dellavalle Laboratory, Inc	39
Session III. Plant Nutrition	40
Tracking Nutrient Budget Trends using NuGIS R.Mikkelsen, Western North America IPNI	41

Best Management Nutrient Practices for Nut Crops R.H. Beede, UCCE Kings and Tulare Counties	44
Nitrogen Transformations, 15N Assimilation and Recovery for California Almonds D. L. Schellenberg, Dept. of Viticulture and Enology, UC Davis	53
N Management: Almonds where we been, where we are going? G. Ludwig, Almond Board of California	56
Remediation of tile drain water using denitrification bioreactors T.K. Hartz, Dept. of Plant Sciences, UC Davis	57
Improved Methods for Nutrient Tissue Testing in Alfalfa D. Putnam, Dept. of Plant Sciences, UC Davis	60
Session IV. Crop Production & Mechanization	66
Mechanical Harvesting of Table Olives: California and Spain L. Ferguson, Dept. Plant Sciences, UC Davis,.....	67
Mechanical Canopy and Crop Load Management of Wine Grapes S. Kaan Kurtural, Bronco Wine Co. & Dept. of Viticulture and Enology, California State University, Fresno.....	69
Denele Respiration Rate (D.R.R.) J. Mullinax, Denele Analytical, Inc. Environmental and Agricultural Analysis	74
Sorghum for Forages and Biofuel: Breeding and Improvement J. A. Dahlberg, UC-ANR Kearney Agricultural Research and Extension Center	75
Breeding Almonds for Kernel Quality C. Ledbetter, USD-ARS Crop Diseases, Pests and Genetics Lab. Parlier, CA.	79
Screening and Selection for Fusarium Race 4 Resistance in Cotton R. B. Hutmacher, UC-ANR West Side Research & Extension Center	80
Session V. Water Management	83
Soil Moisture Sensor Phase II Virtual Test for Irrigation Association D. D. Adhikari, Center for Irrigation Technology, California State University Fresno	84

Integrating Soil Moisture Monitoring into Irrigation Management B. Ferri, Almond Grower and California State University, Fresno.....	88
CropManage – A Web-based Irrigation and Nitrogen Management Tool M. Cahn, UC Cooperative Extension, Monterey County.	90
Designing Irrigation Systems to Manage Variable Soils B. Bassett, H2O Optimizer, Hanford, California	96
Water Management Strategies for Table Grapes I. Abrisqueta, USDA-ARS, Water management Research Lab., Parlier, CA.....	105
Regional assessment of vineyard water use in the Central Coast: The Paso Robles Groundwater Basin M. Battany, UC Cooperative Extension, SLO	113
Session VI. Soil Salinity & Managing Soil Quality.....	116
New Soil Survey Applications to Investigate California's Soil Resource A. O’Geen, Department of Land, Air and Water Resources, UC Davis.....	117
Herding Nitrogen, Herding Cats: Recent Improvements, Continuing Challenges, and Possible Solutions for California Agriculture S. Pettygrove, Department of Land, Air and Water Resources, UC Davis.....	120
Beyond Conservation Tillage: Merging Technologies for Greater Efficiencies J. Mitchell, Department of Plant Sciences, UC Davis	127
Reducing Sediment loss and Protecting Water Quality in Coastal Vegetables M. Cahn, UC Cooperative Extension, Monterey County	130
Water Quality Criteria for Use of Saline/Degraded Water for Irrigation D. L. Suarez, USDA/ARS Salinity Laboratory, Riverside CA.	136
Salinity and Drainage Management in the Western San Joaquin Valley—Where are we Today? S. Benes, Dept. of Plant Science, California State University, Fresno	141
2013 Poster Abstracts	146
Notes	161
Plant and Soil Conference Evaluation Form	168

PAST PRESIDENTS

YEAR	PRESIDENT	YEAR	PRESIDENT
1972	Duane S. Mikkelsen	2010	Larry Schwankl
1973	Iver Johnson	2011	Mary Bianchi
1974	Parker E. Pratt	2012	Allan Fulton
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		
2002	Dave Zodolske		
2003	Casey Walsh Cady		
2004	Ronald Brase		
2005	Bruce Roberts		
2006	Will Horwath		
2007	Ben Nydam		
2008	Tom Babb		
2009	Joe Fabry		

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	2013	Harry Cline
1988	Duane S. Mikkelsen		Vince Petrucci		Clyde Irion
1989	Donald Smith		Ken Tanji		Charles Krauter
	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				

2012 Chapter Board Members

Executive Committee-President

Allan Fulton
UCCE- Tehama County
1754 Walnut Street
Red Bluff, CA 96080
(530) 527-3101 – Office
(530) 527-0917 – Fax
(530) 200-2246 – Cell
aeffulton@ucdavis.edu

First Vice President

Dave Goorahoo
Associate Professor
Dept of Plant Science
2415 E. San Ramon Ave, M/S AS72
Fresno, CA 93740-8033
(559) 278-8448 – Office
(559) 278-7413 – Fax
dgooraho@scufresno.edu

Second Vice President

Steve Grattan
Plant-Water Extension Specialist
Dept LAWR/Veihmeyer
One Shields Avenue
Davis, CA 95616
(530) 752-4618 - Office
(530) 752-5262 - Fax
(530) 304-1201 – Cell
srgrattan@ucdavis.edu

Executive Secretary-Treasurer

Richard Smith
UCCE – Monterey County
1432 Abbott Street
Salinas, CA 93901
(831) 759-7357 - Office
(831) 758-3018 - Fax
(831) 596-7086 – Cell
rifsmith@ucdavis.edu

Past President

Mary Bianchi
UC Cooperative Extension
San Luis Obispo County
2156 Sierra Way Ste. C

San Luis Obispo, Ca 93401
(805) 781-5949 – Office
(805) 781-4316 – Fax
(805) 440-1805 – Cell
mlbianchi@ucdavis.edu

One Year Term

Danyal Kasapligil
Dellavalle Laboratory
502 Mace Blvd suite 2B
Davis, CA 95618
(800) 228-9896 - Lab
(831) 750-4509 - Cell
(530) 757-5553 - Fax
danyal@dellavallelab.com

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
(916) 324.9006 – Fax
mfossen@cdpr.ca.gov

Rodrigo Krugner, Ph.D.
Research Entomologist
USDA-ARS, San Joaquin Valley
Agricultural Sciences Center
Crop Diseases, Pests and Genetics
Unit
9611 S. Riverbend Avenue
Parlier, California 93648
(559) 596-2887 - Office
(559) 596-2921 - Fax
Rodriqo.Krugner@ars.usda.gov

Two Year Term

Florence Cassel-Sharma
Assistant Professor
CIT and Dept. of Plant Science
Calif. State University, Fresno
2415 E. San Ramon Ave, M/S AS72
Fresno, CA 93740-8033
(559) 278-7955 (office)
(559) 278-7413 (Fax)
fcasselss@csufresno.edu

Richard Rosecrance
Associate Professor
College of Agriculture
400 W 1st St
CSUC
Chico, CA 95929-0001
(530) 898-5699 Office
(530) 898-5845 Fax
rosecrance@csuchico.edu

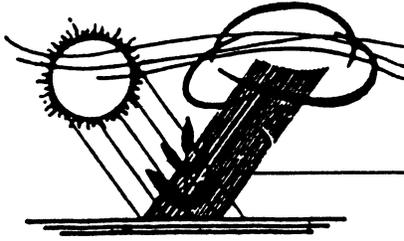
Toby O'Geen
Specialist in CE
Dept of LAWR/PES
University of Calif – Davis
One Shields Ave
Davis, CA 95616
(530) 752-2185
atoqeen@ucdavis.edu

Three Year Term

Anil Shrestha
Associate Professor, Weed Science
Dept. of Plant Science
California State University
2415 E. San Ramon Ave. MS A/S 72
Fresno, CA 93740
Phone: 559-278-5784
Fax: 559-278-7413
ashrestha@csufresno.edu

Bob Hutmacher
Extension Cotton Specialist and
Director, West Side REC
West Side Research & Extension
Center
17353 West Oakland Avenue
Five Points, CA 93624-0158
(559) 260-8957
rbhutmacher@ucdavis.edu

Warren Hutchings
Agronomist
Innovative Ag Services, LLC
1201 Lacey Blvd, Suite 5
Hanford, CA 93230
(559)-587-2800 (office)
(559)-587-2801 (fax)
whutchings@innovativeag.net



**California Chapter
AMERICAN SOCIETY OF AGRONOMY**

February 8th, 2012

**Minutes for 2012 Board Meeting
California Chapter of the American Society of Agronomy (ASA)**

**February 8, 2012
Holiday Inn
Visalia, CA
12:35 PM – 1:30 PM**

- 1. Call to Order:** Mary Bianchi, President, California Chapter ASA.
 - a. Welcomed attendees to the 40th annual business meeting of the California Chapter ASA. Noted that the society annual meeting has long been running since 1972. One of the longest running conferences in California...and one that still receives proceedings.
 - b. Larry Schwankl was thanked for scanning and posting all of the past proceedings on the ASA website.
 - c. Acknowledged that like 2010 and 2011 the conference is again being conducted in cooperation with the California Certified Crop Advisors (CCA).
 - d. Student attendees were acknowledged and asked to stand and be recognized. Many came from CSUF, College of the Sequoia, UC Davis, and others.
 - e. Acknowledged and thanked the sponsors for refreshments for the breaks.
 - i. Innovative Ag Services, LLC
 - ii. BWC. Buttonwillow Warehouse Company
 - iii. Valley Tech-Agricultural Laboratory Services
 - f. President Bianchi introduced the Executive Committee and Governing Board and thanked members for their hard work for preparing yet another ASA Plant and Soil Conference. She emphasized that all Board member positions are volunteered. This Mary's 7th year. She recognized the members along with Lois Strole for her outstanding help with registration.
 - i. Past President, Larry Schwankl (Honorees)
 - ii. 1st VP, Allan Fulton (Proceedings)
 - iii. 2nd VP, Dave Goorahoo (Conference site arrangements)
 - iv. Secretary and Treasurer, Steve Grattan (Registration)
 - v. Governing Board (Carol Frate, Brad Hanson, Nathan Heeringa, Matt Fossen, Rodrigo Krugner, Danyal Kasapligil, Florence Cassel-Sharma, Toby O'Geen, and Rich Rosecrance).
 - g. Mary introduced and thanked Past Presidents and individuals who served on the Governing Board of the Chapter.

2. **Business meeting minutes from the 2011 ASA Plant and Soil Conference** (Bianchi)
 - a. Indicated that the minutes of the Feb. 1, 2011 conference was on page 11 of the proceedings
 - b. Motion to approve the minutes was given (Fulton) and seconded (Grattan). Minutes for the 2011 business meeting passed.
3. **Treasurer's Report** (Grattan)
 - a. Presented Treasurer's report for the 2011. \$26,957 is the current balance in the CA Chapter ASA account. Charges and credits for this year's conference are pending.
 - b. Approval of Treasurer's report was moved (Carol Frate) and seconded (Keith Backman). Motion passed to approve Treasurer's report.
4. **Nomination and Election of persons to serve on the Governing Board** (Bianchi)
 - a. Brief overview of the Governing Board structure was provided: 9 persons serving 3-year terms. According to by-laws, members on the Board represent diverse disciplines and represent academia, agencies and industry.
 - b. The past President and Board members completing their term of service were acknowledged and thanked for their dedication and hard work.
 - c. Nominations opened for the election of persons to serve on the 2012 Governing Board.
 - d. Board nominations for the Executive Committee and Governing Board were presented:
 - i. Allan Fulton as President
 - ii. Dave Goorahoo as 1st VP
 - iii. Steve Grattan as 2nd VP
 - iv. Richard Smith as incoming Secretary/Treasurer
 - v. Serving 3 year terms
 1. Bob Hutmacher, UC Davis, WREC
 2. Anil Shrestha, CSUF
 3. Warren Hutchins, Innovative Ag Services
 - vi. Motion was made, seconded and passed to approve new members
5. **Presentation of awards to 2012 honorees.** (Schwankl)
 - i. Dr. Bob Matchet
 1. Bonnie Fernandez introduced Dr. Matchet
 2. Bonnie gave summary of Bob's past accomplishments, particularly in regards to his contributions to the wheat and grain industry in California.
 3. Award was presented and Dr. Matchet thanked and acknowledged those who helped him over the years beginning in 1968.
 - ii. Don May
 1. Blaine Hanson, one of last years California Chapter ASA honorees, gave a brief overview of Don May's accomplishments over his career.
 2. Don started in 1958 as Farm Advisor and became an authority on processing tomato. He acknowledged his hard work and persistence.
 3. Award was presented to Don and, while holding back tears, he thanked those who have helped him over this career.
 - iii. Terry Prichard
 1. Larry Schwankl introduced Terry Prichard. Larry acknowledged Terry's great expertise in water management, particularly in regards to salinity issues in the delta and regulated deficit irrigation of wine grapes. Larry acknowledged Terry's unique ability to translate difficult

research information into very understandable information to diverse audiences.

2. Terry thanked those who have helped him over the years. He thanked UC Specialists, Farm Advisors, USDA and others. He also acknowledged the upcoming younger generation and his wife.

6. Student Posters and Scholarships

- a. Brad Hanson (Chair of student scholarship committee).
 - i. Brad acknowledged other committee members.
 - ii. Brad briefly discussed the criteria used to judge the students.
 - b. Winning essays we announced and Keith Backman announced the rewards. The funds we provided by Western Plant Health Association (\$1500) plus those who donated to funds to the student scholarship funds. A three-way tie for 1st place was awarded.
 - i. Stacy Hack
 - ii. Luke Milliron
 - iii. Sonia Rios
 - c. Rodrigo Krugner announced awards for student posters.
 - i. Two first place for Undergraduate and two for Graduate students
 - ii. Tari Lee Frigulti and Sonia Rios (1st place tied) UG
 - iii. Grad student 2nd place Bardia Dehghanmanshadi
 - iv. Maya Bellow and Daniel Bair (1st place tied) for best poster.
- 7. Old business and New business** (none was introduced)
 - 8.** President Bianchi asked those attendees to fill out conference evaluation forms.
 - 9.** Mary passed the feared gavel (made special for the ASA California Chapter made in 1978) over to Allan Fulton, the new incoming President.
 - 10.** Newly elected President Fulton presented award to President Bianchi for her hard and excellent work over the years.
 - 11.** Allan ended the business meeting with a resounding thud of the feared gavel.



American Society of Agronomy

California Chapter

2013 Honorees

Harry Cline

Clyde Irion

Charles Krauter

Harry Cline **Editor Western Farm Press**

Harry Cline, began his journalism career as a “copy boy” for the Dallas Morning News while still in high school. He pursued his love of journalism by pursuing a journalism degree from the University of Texas. Following college he worked on newspapers in West Texas. In 1968 he moved further west to Tucson, Arizona where he worked as a reporter for the Tucson Daily Citizen. There he developed a keen interest in Western agriculture. That fascination with agriculture took him to Fresno, Calif. where he became a full-time agricultural journalist, writing for California Arizona Cotton, California Grape Grower and other magazines. In 1978 Harry was appointed as the first editor of the CA/AZ Farm Press which today is known as the Western Farm Press. All totaled, Harry has logged 50 years as a working journalist. .

Harry has witnessed and reported on a remarkable period of change in western agriculture. He has served as a member of the California Chapter of the American Society of Agronomy executive council and received the 1993 California Association of Pest Control Advisors Outstanding Contributor to California Agriculture Award. In 2002, Harry received the California Weed Science Society’s Award of Excellence and in 2012 was made an honorary member to the Western Society of Weed Science.

In his capacity as Editor of Western Farm Press, Harry has provided a significant service to agricultural producers in Arizona and California. He has accomplished this through the timely delivery of balanced information to his readers. Harry has reported on new discoveries, techniques and practices to promote better agriculture. His style and format, used in the Western Farm Press (WFP) is the most “user friendly” and widely read information available. The WFP is known for its accuracy and informative reporting and Harry Cline is a major reason for this publication’s notable reputation. His columns and photos on research and grower practices would outnumber university publications produced during this same period. And where scientific publications fall short in direct delivery of useful information on improved management practices, Harry has ensured that new farming technologies are the topics of morning discussions around coffee shops throughout California and the west. Many of Harry’s stories advanced beyond the coffee shop debates to result in changed practices for western growers.

Harry has been an important agent of change for western agriculture. He initiated a series of Pima Summit meetings, co-sponsored by UC Cooperative Extension, that led to growers approving Pima production in California. He single-handedly kept this program going until all the available information was delivered to Pima growers. This annual meeting was instrumental in helping promote and establish Pima production in the San Joaquin Valley. He also spearheaded grower symposiums on Narrow-Row Cotton Systems in the San Joaquin Valley and Upland Cotton production in the Sacramento Valley that altered how cotton was grown in California.

Harry was instrumental in establishing the Western Farm Press’s High Cotton Award almost 20 years ago. This award recognizes individuals who make significant contributions to the cotton industry through their high production and environmental stewardship. The award has become a

major acknowledgement of the environmental efforts of many of the industry's most progressive producers across the United States Cotton Belt.

Harry's agricultural "beat" covers the entire waterfront of agriculture production concerning western grown high value commodities. From research results to grower experiences with new innovative approaches to marketing opportunities, Harry provides useful information to his readers. In his WFP editorials, Harry has been a strong proponent and a voice of common sense for the bio-engineered technology for crop improvements. He reports sound scientific information on the changes that are occurring in modern agriculture and the real challenges it faces of feeding the future's growing population.

Harry Cline has made a significant contribution to western agriculture and to California through his excellent and accurate reporting of changing production practices and important issues over the past 50 years. Of the honorees recognized by this chapter of the American Society of Agronomy, it is fitting to acknowledge an individual who serves our industry by communicating the success of American agriculture. He believes that California is the "best place in the world to be an agriculture journalist." Harry Cline stands out as the strongest voice telling our story while also helping deliver reliable information to the agricultural community.

Harry has received additional awards from the Arizona Press Club, the American Agricultural Editors Association, and the Turf and Ornamental Communicators Association. He is married to his high school sweetheart, Georgann and has two children, five grandchildren and one great grandson.

Clyde Irion

Retired Agronomist

Clyde was born in Lindsay, California, where he worked with his father growing olives. He graduated from UC Berkley in 1951 with a BS in Organic Chemistry, continuing to farm with his father and then farming olives on his own for seven years.

In 1974 he went to work as manager of Murrieta Farms, a 10,000 acre operation on the Westside of the San Joaquin Valley. He farmed cotton, tomatoes, alfalfa, and wheat. In his 12-year tenure with Murrieta Farms, he cooperated with the University of California Shafter Field Station and V.T. Walhood concerning cotton projects, and the UC Five Points Field Station examining the re-use of saline drainage water for irrigation of melons & tomatoes. This work was published in California Agriculture in 1987, where Clyde was acknowledged for his efforts and cooperation.

In 1985 he was named Cotton Farmer of the year.

Following this employment, he joined Actagro Inc. He worked in product development in the early stage of his tenure. He also worked in the field with many Westside and Eastside growers and Actagro sales people developing sound agronomic practices. The crops he specialized in were blueberries, tomatoes, almonds, and pistachios. In blueberries he traveled to many areas to acquire farming techniques, variety knowledge and fertility practices. He was a valuable asset for blueberry growers.

David Munger summed it up best:

“Clyde is a man of integrity and over the years a father-figure to me.

He can look at a pistachio or almond tree, even a blueberry plant, tells you the problem before any tests are done and be right almost every time.

Clyde is a natural at bringing together the complex technical research and knowledge of agriculture and actual farming practices. It is rare to find someone as genuine and humble as Clyde and I am honored to know him and call him my friend.”

Clyde began a well deserved retirement after 26 years with Actagro LLC.

Charles Krauter
Professor Emeritus, Plant Science Department, CSU Fresno

Charles F. Krauter is a native of California, born and raised near Bakersfield. He graduated from Arvin High School in 1965 and attended Bakersfield Community College (BC). He worked on the family farm and then for DiGiorgio Fruit Co. as a lab and field assistant. While at BC, he began working for the UC Cooperative Extension (UCCE) as a summer assistant to the Farm Advisors in the Kern County office. He transferred to UC Davis in 1967, majoring in Soil and Water Science and continued to work for UCCE during the summers. After finishing his BS in Soils in 1970, he remained with Cooperative Extension as the field technician for three state-wide specialists in the Water Science Department at Davis. That enabled him to continue in graduate school as well as participate in several research programs, notably some of the first field studies that monitored nitrate leaching from crop fertilization. He co-authored his first paper, on nitrate profiles, at the 1972 Plant and Soil Conference in Fresno.

In 1974 he completed a Ph.D. in Soil Science and began a teaching career in the agriculture department back at BC. It was there that he developed the course in agricultural water that he taught every semester since 1975, and still teaches each Fall semester! In 1979, he and his family moved to Fresno as he accepted the irrigation position in the Plant Science Department at Fresno State. The opportunity to combine teaching with research and professional involvement were the benefits of moving to Fresno State. While problems of salts and pesticide leaching continued to be a research priority, the advent of CIMIS and the use of small computers to model plant water use were additions to his teaching and research programs. In 1996, he began a cooperative effort with an atmospheric science group at NASA's Ames Research Center to help model emissions from agricultural practices. In 1999 they began a major project to model ammonia emissions after fertilizer applications. That work led to further studies related to ammonia, VOC and other air emissions from cultivation and dairy operations. In 2004, Dr. Krauter received the CSU Fresno Provost's Award for Distinguished Achievement in Research and Scholarship and in 2007 he was presented with the College of Agriculture's Award for Research. He has been a member of the CA-ASA all his career and was elected to the board in 1988 and again in 2004. He is also a member of the Professional Soil Scientists Association of California (PSSAC) and served on their board from 1996 to 2010. He was PSSAC president in 2005-07. He retired from full time teaching and research in December of 2009, though he continues to teach part time in the department and be a source of information and advice for other faculty members.

Dr. Krauter is married to the former Cheryl Powers. They met as community college students in 1967. He and Cheryl live east of Clovis and have a son, daughter and three grandchildren. With teaching and grandfathering, it is amazing that Charlie still manages to find time for gardening, racing his sailboat, driving old sports cars, wandering around in the mountains, reading and going to meetings to visit with old friends.

CALASA is proud to honor Dr. Charles Krauter for his contribution to the advancement of California's agriculture....Congratulations Charlie!



American Society of Agronomy

California Chapter

2013 Scholarship Recipients & Essays

Essay Question:

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

Scholarship Committee:

Florence Cassel-Sharma, Chair

Mary Bianchi

Rodrigo Krugner

Anil Shrestha

2013 Scholarship Award Winners

1st place: Sarah Gooder, Cal Poly SLO

Green energy has a reciprocal relationship with agriculture. Not only can California's agricultural industries contribute to state and federal green energy initiatives, but agriculture can benefit from these plans as well.

According to the Union of Concerned Scientists, "Wind energy alone could provide \$1.2 billion in new income for farmers and rural landowners by 2020, as well as 80,000 new jobs." In addition to providing their own power, farmers have the option of leasing their land to wind developers or instead becoming a developer. Besides harvesting the wind, solar energy is another viable option for green energy. Farmers should select this choice to "save money, increase self-reliance, and reduce pollution...and make the farm more economical and efficient." After all, the sun can be the answer to drying crops, powering irrigation pumps, and so much in between.

Pyrolysis and gasification are two promising processes that ultimately yield sustainable energy from sustainable agriculture. With pyrolysis, organic matter is chemically decomposed under high temperatures and without oxygen. Gasification is a similar process, however there is some oxygen used. Either way, products include fuel, biochar, and tar. In addition, "Bio-gasses created by combustion can be converted into ethanol and biodiesel as well as burned directly" as we learn from John Ikerd in his article, "Sustainable Energy from Agriculture; Food and/or Fuel." In turn, carbon that is isolated from the biochar can later be put back into the field, thereby increasing soil fertility through synergistic relationships. When farmers can use this system, they are able to cater to their own needs of producing fuel for their farm and home, all while saving the natural productivity of their soil.

The ideas in this essay are just a few of the many examples of the effects agriculture has on green energy, and vice versa. Ultimately, this is a step in the right direction to ensure California's agriculture industries stay on top for thousands of years to come.

2nd place: Hannah Ramey, CSU Chico

Green Energy from Red Algae

Green energy initiatives will benefit California agriculture industry in three primary ways, conservation compliance, increased revenue, and increased food production. A green energy solution that I propose California could contribute is the recycling of nitrate- and phosphate- rich runoff from agricultural lands to grow algae for biofuel.

As water runs off of farm land and into the Gulf of Mexico, the rate of eutrophication increases, causing the water to become hypoxic. California is looking for ways to conserve and properly distribute water. Federal and State proposals for increased alternative energy production have long been unmet. Current research suggests a green energy solution is to use red algae as biofuel. The high levels of nitrates and phosphates in the runoff water could be used to grow algae; the algae could sequester the otherwise harmful and wasted nutrients, and then could be harvested for biofuel. If California and Federal green energy initiatives were to address using algae for biofuel, the agriculture industry would benefit in several ways.

Conservation behooves farmers, not only because they will continue to be able to grow products for many generations, but because consumers are becoming increasingly interested in the environmental practices involved in producing their food. If Federal and State green energy initiatives employed the use of agriculture products, the benefits to the rich agriculture lands of California would be even greater. According to the United States Government Accountability Office, the United States Department of Agriculture has presented one hundred five renewable energy initiatives, demonstrating just how important it is that these initiatives are agriculturally conscious. Green energy such as bioenergy can use animal manure as a fuel source, creating more revenue for the farmers and turning a “useless nuisance” into a profitable product. If the renewable energy crops like algae can be grown on marginal land, as energy becomes more expensive from higher demand, production of non-food energy crops and manure for biofuel will allow for more food crops to be grown.



American Society of Agronomy

California Chapter

General Session

Keeping California Agriculture
Proactive and Innovative

Session Chair:
Allan Fulton

Small Steps or Quantum Leaps: How will California Horticulture Maintain its Competitiveness?

Nick Dokoozlian

Vice President, Viticulture, Chemistry, and Enology
E&J Gallo Winery
600 Yosemite Blvd
Modesto, CA 95354

Nick.Dokoozlian@ejgallo.com

Phone: (209)-341-7760; Fax: (209)-581-1159

Backup contact: **Kari Severe**

Same office phone number

Kari.severe@ejgallo.com

NOTES & QUESTIONS



American Society of Agronomy

California Chapter

Session I
Pest Management

Session Chairs:
Rodrigo Krugner
Anil Shrestha
Matt Fossen

Research-Based *Tomato spotted wilt virus* Management Plan in Central California Processing Tomatoes

T. A. Turini, University of California, Agriculture and Natural Resources, Fresno County 1720
S. Maple Ave., Fresno, CA 93702

Phone: 559-375-3147, FAX: 559-600-7228, taturini@ucanr.edu

R. L. Gilbertson, University of California, Department of Plant Pathology, One Shields Ave.,
354 Hutchinson Hall, Davis, CA 95616

Phone: 530-600-7228, rlgilbertson@ucdavis.edu

M. Le Strange, University of California, Agriculture and Natural Resources, Tulare/Kings
Counties, 4437-B S. Laspina St., Tulare, Ca 93274

Phone: 559-684-3300, FAX: 559-685-3319, mlestrange@ucanr.edu

O. Batuman, University of California, Department of Plant Pathology, One Shields Ave., 354
Hutchinson Hall, Davis, CA 95616

Phone: 530-600-7228, obatuman@ucdavis.edu

C. S. Stoddard, University of California, Agriculture and Natural Resources, Merced/Madera
Counties, 2145 Wardrobe Ave., Merced, CA 95341

Phone: 209-385-7403, FAX: 209-722-8856 csstoddard@ucanr.edu

E. M. Miyao, University of California, Agriculture and Natural Resources, Yolo County, 70
Cottonwood St., Woodland, CA 95695

Phone: 530-666-8732, FAX: 530-666-8736 emmiyao@ucanr.edu

D. E. Ullman, University of California, Department of Entomology, One Shields Ave., 150 Mrak
Hall, Davis, CA, 95616

Phone: 530-752-7150, FAX: deullman@ucdavis.edu

N. McRoberts, , University of California, Department of Plant Pathology, One Shields Ave., 354
Hutchinson Hall, Davis, CA 95616

Phone: 530-752-3248, nmcroberts@ucdavis.edu

Introduction

An evaluation of the biology of *Tomato spotted wilt virus* (TSWV) and the thrips vector began in 2005, which was shortly after devastating losses due to this virus in the Fresno processing tomato production area. Area assessments of tomato and other crops, weeds, transplant houses were conducted to determine the sources of the virus, seasonal population fluctuation of thrip and virus incidence were evaluated in assessments of tomato fields, other crops, weeds and transplant houses. In addition, integrated pest management strategies, which incorporate crop planning, sanitation, variety selection and insecticides, were evaluated over a six year study. The integrated pest management program developed depends upon reduction of weed hosts, crop planning, and use of plant resistance and insecticides. Extension of findings was accomplished through extension meetings, publications and e-mail updates of regional thrips

population densities and TSWV incidence. Future efforts include validation of a risk assessment model, evaluation of the importance of role of pupating thrips as a source of the virus in spring, deeper study into symptom expression in TSWV-resistant varieties, and development of alert systems through mobile technologies.

Methods

Sources of TSWV in Spring: In the absence of tomatoes, other crops were evaluated that might serve as winter hosts. Over the duration of the trial, 12 almond orchards, 15 lettuce fields, 6 fields of other host crops and 5 non-host crops, and 3 transplant houses (5 years), were monitored with yellow sticky cards and fava bean indicator plants. Over 400 weed samples were collected and tested for TSWV. Soil was collected from 12 fields in March in 2011-12, taken to a greenhouse and held at 78°F for three weeks, emerging thrips were tested molecularly and in indicator-plant transmission studies.

Development in tomatoes: During the 6-year study, 134 tomato fields were monitored for TSWV and thrips population densities, which was determined based on number of thrips found on 4 cards per field collected every 7 to 14 days. As cards were being collected and replaced, TSWV incidence was evaluated. Furthermore, TSWV was evaluated at the same time interval at four locations per field.

Variety comparison: From 2007 to 2012, TSWV-susceptibility of processing tomato cultivars were evaluated in 13 replicated trials, which each evaluated from 10 to 18 varieties. In each trial, entries were evaluated within 14 days of harvest and TSWV symptom incidence was recorded, percentage of plants expressing symptoms was calculated per plot, analyzed and all entries were tabulated together and based on overall results, relative susceptibility of all entries included in at least three different trials were ranked based on performance.

Insecticide evaluations: Novel and registered insecticides were evaluated for efficacy against Western flower thrips, *Frankliniella occidentalis*, in trials conducted in Fresno County from 2007 through 2012. In addition, the impact of insecticide programs, including materials applied through the drip irrigation system, either alone or in combination with 2 to 5 applications of foliar materials were compared in studies from 2009-2012.

Results:

Tomato spotted wilt virus has been detected in weeds, as well as in lettuce, radicchio and fava bean, which could serve as a source in spring (Fig. 1). The virus was not associated with the transplant houses or almond orchards. It is detected in weeds, primarily sowthistle and prickly lettuce (Table 1). In early spring, the virus is present in very few weeds and probably in some thrips pupae as well. As temperatures increase, thrips become more active and fly from infected plants, where they acquired the virus as an immature. As temperatures increase, generation time for Western flower thrips declines quickly and population densities increase (Fig. 2).

Varieties consistently differed in relative susceptibility. Although the resistant varieties consistently had very low levels of disease or none, there were differences among varieties without genetic resistance (Table 2).

Insecticides can be a component in TSWV IPM. Because the thrips must acquire the virus in the immature stage to be capable of transmission as an adult and because the virus is persistent within the vector (Ullman et al., 1993; Whitfield et al., 2005), it is likely that the secondary spread within a field may be reduced with insecticide programs. However, few insecticides have consistently shown efficacy against *F. occidentalis*, the most common species on tomatoes in San Joaquin Valley. Those that have are Radiant, Spinosad, dimethoate, Lannate and Beleaf has also reduced populations in comparison to the untreated (Table 3). Programs of these efficacious materials rotated with materials with different modes of action have shown promise in reducing TSWV incidence in 3 of 4 trials. However, when very high thrips populations were entering the field with the virus, it is unlikely that insecticides will provide a reduction in virus levels. Resistance development in thrips is a risk, so an insecticide rotation is strongly recommended (Herron and James, 2005). Neonicotinoid insecticides applied through buried drip irrigation systems did not provide control under the conditions of this study. It is strongly advised that neonicotinoids not be used as the primary tool for reducing thrips population densities.

Integrated Pest Management Program for TSWV in Processing Tomatoes (Gilbertson et al., 2011)

Before the growing season

Consider planting TSWV-resistant tomato varieties (i.e., with the *Sw-5* gene). Varieties without the *Sw-5* gene differ in disease susceptibility.

- Use virus- and thrips-free transplants (from greenhouses that monitor thrips and inspect transplants).
- Manage thrips populations on transplants in the greenhouse, if necessary.

During the growing season

- If planting near established fields with confirmed TSWV infection, an early-timed thrips control program may be needed.
- Monitor fields for thrips (e.g., with yellow sticky cards) and TSWV symptoms.
- Manage thrips with insecticides when populations begin to increase especially when tomato spotted wilt infection are observed. Rotate chemicals to minimize the development of resistance in thrips.
- Consider rouging and removing infected plants if plants are infected at the seedling stage to limit further spread.
- Control weeds in and around fields.

After the growing season

- Promptly disk old crops/volunteers after harvest (preferably on a regional level). Authors: this doesn't apply with canning tomatoes as harvest is a destructive harvest.
- Control weeds/volunteers in fallow fields, non-cropped or idle land near next year's tomato fields.

Sources Cited

Gilbertson, R. L., O. Batuman, M. Le Strange, T. A. Turini, S. Stoddard, E. Miyao and D. Ullman. 2011. *Tomato spotted wilt* disease: Detection, epidemiology and Integrated Pest Management. UC IPM.

Herron, G. A., T. M. James. 2005. Monitoring insecticide resistance in Australian *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) detects fipronil and spinosad resistance. *Australian Journal of Entomology*. Volume 44, Issue 3, pages 299–303.

Ullman, D. E., T. L. German, J. L. Sherwood, D. M. Westcot and F. A. Cantone. 1993. Tospovirus Replication in insect vector cells: Immunocytochemical evidence that the nonstructural protein encoded by the S RNA of Tomato Spotted Wilt Tospovirus is present in the thrips vector cells. *Phytopathology*. 83:457-463.

Whitfield, E., D. E. Ullman and T. L. German. 2005. Tospovirus-Thrips Interactions. *Annu. Rev. Phytopathol.* 2005. 43:459–89.

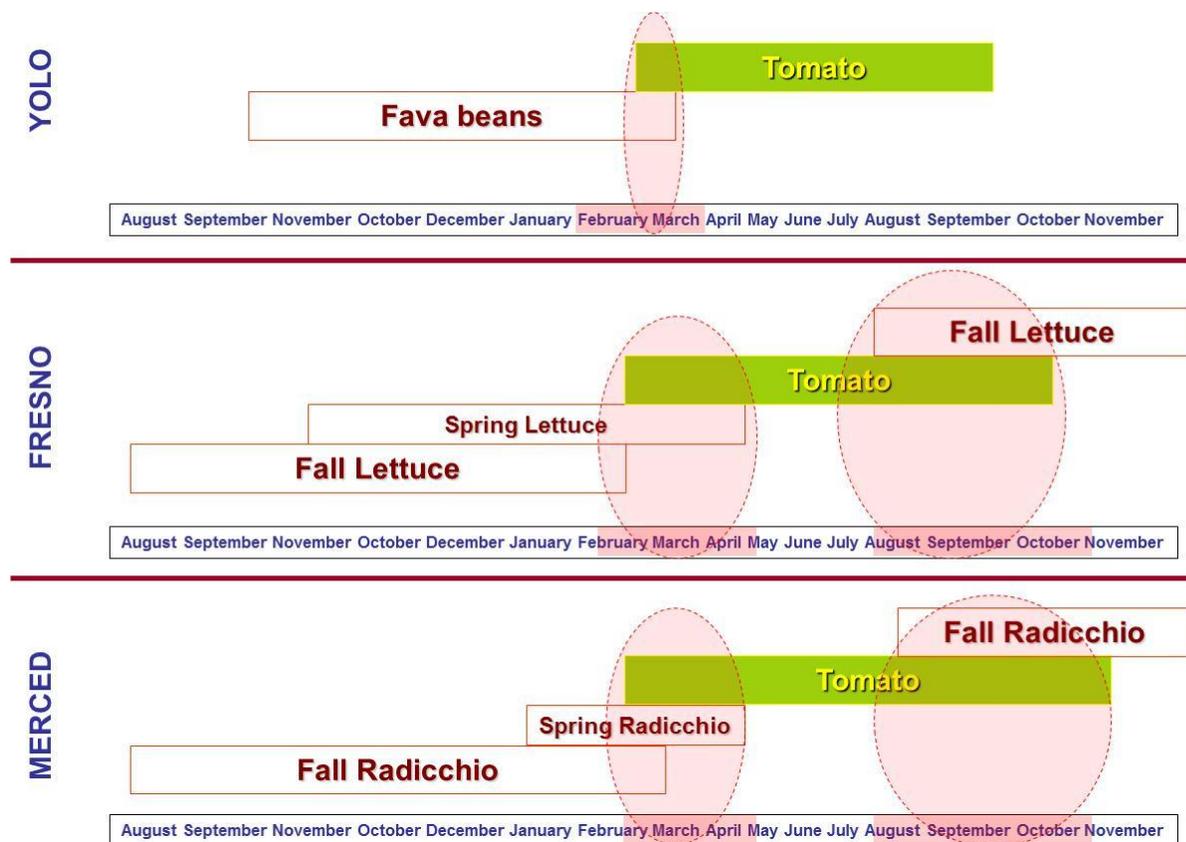


Fig 1. Seasonal movement of *Tomato spotted wilt virus* from crops in three production areas.

Table 1. Weeds tested for Tomato spotted wilt virus in 2012.

Weed ^a	Tested (+)	Weed ^a	Tested (+)
Black nightshade	10 (1)	Curlydock	22 (0)
Bindweed	58 (0)	Malva	68 (0)
Flaree	30 (0)	Datura	10 (0)
Pineapple weed	24 (0)	Monocots	18 (0)
Sowthistle	134 (7)	Shepherd's purse	3 (0)
Prickly lettuce	85 (2)	Fiddler neck	5 (0)
Russian thistle	16 (0)	Pigweed	8 (0)
Buckhorn Plantain	8 (0)	Turkey mullein	15 (0)
Wild radish and Mustard	30 (0)	Other common weeds	38 (0)

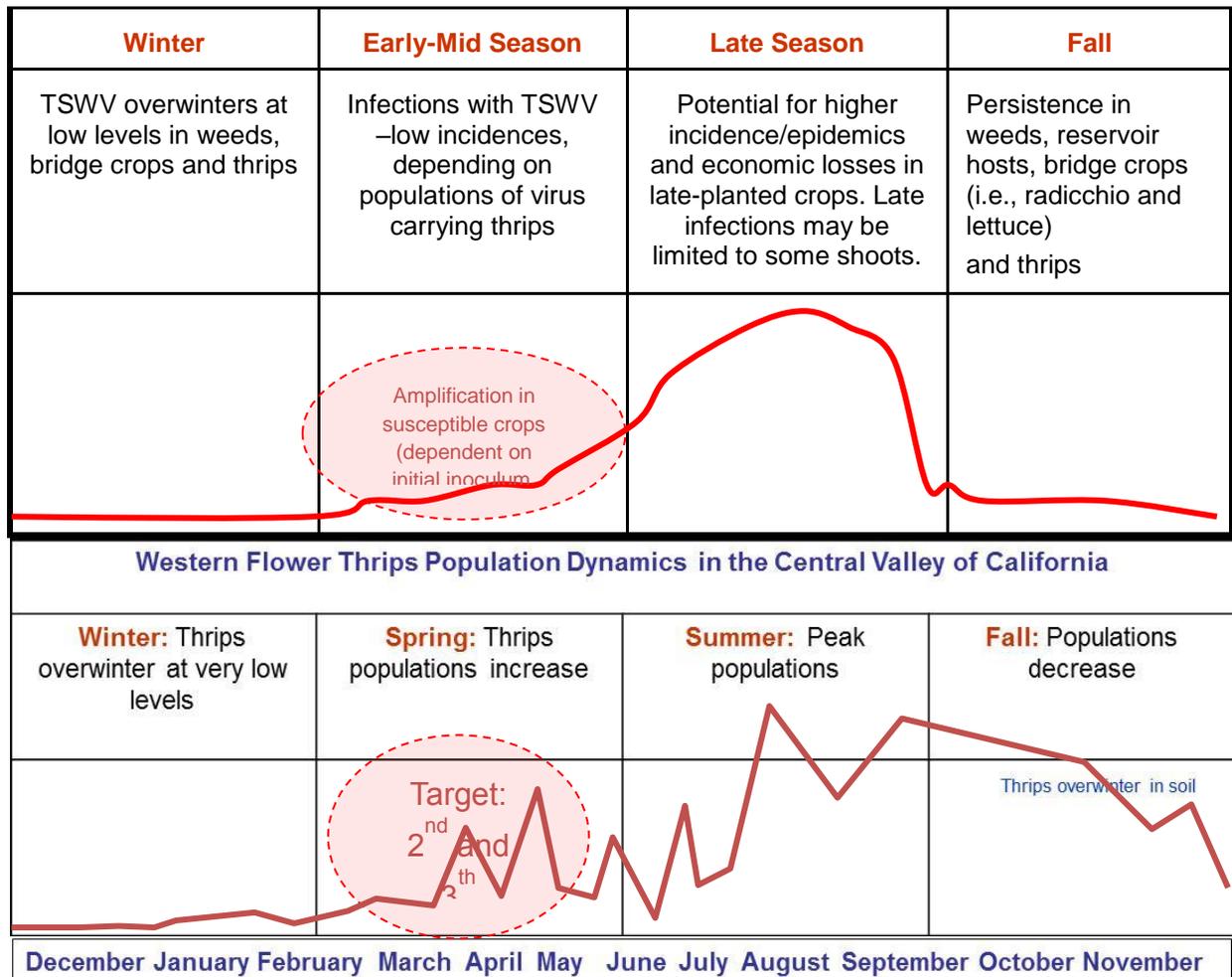


Figure 2. Seasonal development of thrips population densities and TSWV in the Central San Joaquin Valley.

Table 2. Relative susceptibility of processing tomato varieties based on 13 replicated trials conducted in Fresno County from 2007 to 2012.

Genetic resistance		Low		Variable or Medium		High	
AB 8058	paste	BQ 163	paste, peel	H 2005	multi use	H 8004	multi
H 5608	paste	H 2206	multi use	SUN	multi use	BOS 602	multi
N 6394	multi use	UG19406	multi use	H 1015	early	H 8504	paste
H 5508	paste	SUN	peel,	NDM	multi use	HM	multi
H 5608	multi use	H 4007	multi use	CXD 282	multi use	H 2601	pear
N 6385	peel,	K 2769	-----	AB 2	multi use	AB 3	multi
UG	peel	H 3044	multi use	H 9780	multi use	NUN	viscosity
		N 6397	multi use	K 2770	-----	APT410	multiuse
		UG	peel	CXD 255	multi use		
		BQ 205	multi use	HMX	pear		
		UG 4305	multi use	PX 1723	dice, peel		

Table 3. Insecticides that have consistently provided control in Fresno County efficacy trials on tomatoes from 2007-2012.

Trade (common name)	Resistance management class
Radiant (spinetoram) and Success (spinosad)	5
Dimethoate	1B
Lannate (methomyl)	1A
Beleaf (flonicamid)	9C
Mention of trade names is for illustration only, not as an endorsement of any specific product.	

Managing Burrowing Pests in California Agriculture

Roger A. Baldwin, IPM Wildlife Pest Management Advisor,
UC Kearney Ag Research & Extension Center, 9240 S. Riverbend Ave, Parlier, CA 93648
Phone: (559) 646-6583; E-mail: rabaldwin@ucanr.edu

Introduction

Although many vertebrate pests cause problems in agriculture, perhaps the most frequent offenders in California are California ground squirrels (*Spermophilus beecheyi*), pocket gophers (*Thomomys* spp.) and meadow voles (also known as meadow mice; *Microtus* spp.). Ground squirrels are 9 to 11 inches in length (excluding tail), mottled grayish-brown in color, and have a semi bushy tail. They dig extensive burrows that may be 5 to 30 feet long, 2.5 to 4 feet below the surface, and about 4 to 6 inches wide. Pocket gophers are short, stout burrowing rodents, usually 6–8 inches in length. They spend most of their time below ground where they use their front legs and large incisors to create extensive burrow systems. Meadow voles are small, blunt nosed stocky rodents with small eyes and short ears and legs. They are typically dark grayish brown in color with size intermediate to that of a house mouse and a rat.

Ground squirrels reproduce only once per year, but average 8 young per litter. Pocket gophers will breed anywhere from 1 to 2 times per year, although in more southern irrigated alfalfa fields, they may reproduce up to 3 times per year. Female voles may produce from 5 to 10 litters per year. Therefore, continuous monitoring and control of all these burrowing rodent populations is needed to keep their numbers low. Ground squirrel young are born in early to mid spring. Gophers and voles can breed at different times throughout the year; however, there is typically a pulse in reproduction toward the middle of spring. As such, control measures implemented before reproductive pulses of all burrowing rodents will often be more effective as there will be fewer individuals to control at that time. Additionally, because voles mature rapidly and can bear many litters annually, vole populations can increase rapidly. Typically, their numbers peak every 6 to 8 years when population numbers can be as high as hundreds of voles per acre.

If left unchecked, burrowing rodents will cause extensive damage including consumption nuts, fruits, and other vegetative plant parts that result in direct loss of crop production; consumption of tap roots and girdling of stems, trunks, and vines that results in a loss in vigor of the plant; loss of irrigation water down burrow systems; and chewing on irrigation lines. Mounds and burrow openings can also result in additional problems including serving as weed seed beds, burying of plants, and causing damage to farm equipment.

A number of options are currently available for controlling burrowing rodents although most management programs center on toxic baits, fumigants, and trapping. Other control options are available as well, although their efficacy is less clear. I will briefly detail each of these approaches in the following sections.

Toxic baits

Ground squirrels.—Toxic baits are usually the most cost-effective way for controlling ground squirrels, especially large populations and over large areas. Bait consists of grain or pellets treated with a toxin registered for ground squirrel control. To be effective, the bait must be used

at a time of year when ground squirrels are active and feeding on seeds (usually late spring through early summer and again in autumn). Toxic baits registered for ground squirrel control include the acute toxin, zinc phosphide, and anticoagulant baits (diphacinone and chlorophacinone). Zinc phosphide can be applied through spot-treatments or broadcast applications. Spot treatments are used when a small number of burrow systems are treated. This approach involves lightly scattering bait around each active burrow opening. Alternatively, the bait may be broadcast over a larger area using a mechanical seed spreader. Bait shyness can occur with zinc phosphide baits when squirrels ingest a sublethal dose, thereby becoming sick and learning to avoid the bait during future applications. This can result in low efficacy of zinc phosphide baiting programs. Pre-baiting the area with untreated grain 2 to 3 days prior to the application of zinc phosphide may reduce the chances of bait shyness and improve the effectiveness of baiting programs. Control with zinc phosphide is usually achieved within 48 hours of the bait application.

With anticoagulant rodenticides, ground squirrels must ingest several doses of bait over a period of several days. Control is slower but there is less chance of squirrels becoming 'bait-shy'. Another advantage is the availability of an antidote (Vitamin K1) in the event of accidental poisoning of non-target animals (e.g., pets, children, etc.). Anticoagulants can be applied in bait stations, as spot treatments near burrows, or broadcast over larger areas. Be sure to follow the label directions carefully to determine what application method is appropriate.

Bait stations are commonly used to provide bait for squirrels. Various kinds of bait stations can be used, though all are designed to let squirrels in while excluding larger animals. Bait stations should be placed near runways or burrows and should be secured so that they are not easily tipped over. If squirrels are moving into fields from adjacent areas, bait stations should be placed along the perimeter where squirrels are invading, with one station placed approximately every 100 feet (30 m), although more stations may be used when the number of squirrels is high. Bait stations should be checked daily at first, then as often as needed to keep the bait replenished. A continuous bait supply is important because if bait feeding is interrupted, the bait's effectiveness is greatly reduced. Any bait that is spilled should be collected, and wet or moldy bait should be replaced. Successful baiting via bait stations usually requires 2 to 4 weeks. Therefore, bait should continue to be supplied until feeding ceases and no more squirrels are observed.

Spot treatments and broadcast applications of anticoagulants follow the general procedure described for zinc phosphide application. However, with anticoagulants, bait must be reapplied 3 to 5 days after the initial treatment to ensure that squirrels are exposed to a continual supply of bait. Usually, squirrels retreat back to burrows when sick and will die there, although up to 20 to 30% of ground squirrels may die aboveground. As such, be sure to dispose of any visible carcasses to prevent poisoning of any predators or scavengers. Burying within existent burrow systems is a good method as long as carcasses are buried deep enough to discourage scavengers. All rodenticides for aboveground field application are now restricted-use materials, so be sure you are fully versed on all current restrictions for their use before applying for ground squirrel control. Your County Agricultural Commissioner's office is your best source for this information.

Pocket gophers.—There are three baits for pocket gopher control: 1) strychnine, 2) zinc phosphide, and 3) anticoagulants (e.g., chlorophacinone and diphacinone). Both strychnine and zinc phosphide are considered acute toxicants. This means that they kill after a single feeding. Strychnine has typically been promoted as the most effective of the two. Strychnine comes in two concentrations in California: 0.5% and 1.8%. The 0.5% concentration is typically used for hand baiting, while the 1.8% concentration is used both for hand baiting and in a burrow builder. Zinc phosphide is also available for pocket gopher control; it comes in a 2.0% concentration. Bait acceptance can be an issue with zinc phosphide, as it has a distinctive odor and taste that gophers are often averse to. Anticoagulants such as chlorophacinone and diphacinone are multiple feeding toxicants. With these rodenticides, gophers must consume the bait multiple times over the course of 3 to 5 days to receive a toxic dose. This means larger amounts of bait are required to maintain a ready bait supply over this time period. Because of this, acute toxicants are typically preferred over anticoagulants for pocket gopher control. However, there are several new products on the market that contain these same toxicants but utilize a different delivery mechanism for providing the toxicant to the gopher. As such, some of the newer products may be more effective and should be tested.

There are two primary methods for baiting in fields: 1) hand baiting with an all-in-one probe and bait dispenser, and 2) a burrow builder. Hand baiting can be effective if you have relatively few gophers in a field. For this approach, an all-in-one probe and bait dispenser is used to locate a gopher burrow. Once the burrow is located, the bait is directly deposited into the tunnel. The opening left by the probe is then covered up with a dirt clod or rock to prevent light from entering the burrow. When using this method, be sure not to bury the bait with loose dirt as this will limit access to the bait. Typically, it is recommended that burrow systems be treated at least twice to maximize efficacy.

Although hand baiting can be effective for smaller gopher populations, the burrow builder can be a more practical method for treating larger areas. The burrow builder is a device that is pulled behind a tractor on a 3-point hitch and creates an artificial burrow at a set depth. Bait is then deposited at set intervals along the artificial burrow. While engaging in normal burrowing activity, gophers will come across these artificial burrows and consume the bait within. This device must be used when soil moisture is just right. If the soil is too dry, the artificial burrow will cave in, but if it is too wet, the burrow will not seal properly and will allow light to filter in; gophers will not travel down burrows if they are not sealed. Although convenient to treat large areas, the efficacy of this method has varied quite extensively from grower to grower. Experimentation is key to determining the applicability of this approach for each grower.

Voles.—Toxic baits are often the primary management option for controlling voles. Both zinc phosphide and anticoagulants can be used depending on the crop, and both are restricted-use materials for vole control. For voles, baits are applied directly to burrows and runways through spot treatments or broadcast applications. Spot treatments are used when only a few burrows are to be treated. Otherwise, broadcast applications are more efficient. If zinc phosphide is overused, problems with bait shyness can occur. As such, zinc phosphide can only be applied once or twice per year depending on the crop. This problem is not present with anticoagulant baits.

Fumigation

Burrow fumigants can be very effective at controlling ground squirrels and pocket gophers, but are not typically used for voles given the shallow nature of their burrow systems combined with their numerous burrow openings. Primary burrow fumigants are aluminum phosphide and gas cartridges. However, as of January 1, 2012, carbon monoxide producing machines can now be used to apply carbon monoxide to burrow systems. Given the fact that they just became legal in California, researchers are still in the process of collecting data on their efficacy.

Ground squirrels.—Late winter and early spring are the best times to fumigate for ground squirrels as moist soil is needed to hold toxic gases inside the burrow system. Conducting ground squirrel control prior to the birth of young will also dramatically decrease their detrimental effect on the population. However, you must wait to fumigate until after ground squirrels have emerged from hibernation; ground squirrels wall themselves off in their burrows when hibernating so fumigation is not effective at this time. Fumigation is also possible later in the year as long as sufficient soil moisture is present, although it is ineffective when ground squirrels are estivating during the hottest times of the year as ground squirrels again wall themselves off in their burrows. For safety reasons, do not use fumigants in burrows that may extend beneath buildings.

Two primary fumigants are used: gas cartridges and aluminum phosphide. Gas cartridges provide an easy and relatively safe way to fumigate ground squirrel burrows. Typically, one cartridge is used for each burrow that shows signs of activity, although larger burrow systems may require two or more cartridges. For application, the cartridges are ignited and shoved into the burrow fuse first using a shovel handle or stick. The burrow entrance is then sealed with soil to hold the toxic gases within. After sealing the burrow, the applicator should watch nearby burrow entrances; if smoke is observed escaping from other entrances, this means the burrows are connected. If the burrow is believed to be small, then this additional entrance only needs to be sealed. If the burrow appears to be large, an additional cartridge may need to be inserted following the above-outlined protocol.

Aluminum phosphide is a very effective fumigant, often outperforming gas cartridges. When aluminum phosphide tablets come into contact with moist soil in the burrow, they produce phosphine gas, which is highly toxic to any animal. When using aluminum phosphide, treat every active burrow, fill the entrance with a wad of newspaper, and cover with soil. Aluminum phosphide is a restricted-use material for which a permit is required for purchase or use. Application personnel should be trained in the material's proper use and on its potential hazards.

Pocket gophers.—Aluminum phosphide is the primary fumigant used for gopher control; it is quite effective and has a very low material cost. Aluminum phosphide is a restricted-use material; it can only be used by or under the direct supervision of a Certified Applicator. The primary method for applying aluminum phosphide is similar to that of hand baiting. You use a probe to find a gopher tunnel, and drop the label designated number of tablets into the probe hole. The opening is then sealed up with a rock or dirt clod to eliminate light from entering and the toxic gases from exiting the tunnel. Be careful not to bury the tablets with loose soil as this will render them ineffective. Typically, you treat each burrow system twice to maximize efficacy. The key with aluminum phosphide treatments is to only apply when soil moisture is

relatively high. Because of this, fumigation is typically most effective in late winter and early spring. However, fumigation after irrigation can also be a good strategy.

Trapping

Ground squirrels.—Because trapping is time-consuming, it is most practical for small infestations of ground squirrels. Several types of kill traps, including modified pocket gopher box traps, tube traps, and Conibear traps, are effective. Box-type and tube traps are typically placed on the ground near squirrel burrows or runways. Efficacy of these traps is usually increased by prebaiting, which is an activity where bait is supplied for a period of several days before activating the trigger mechanism. Once squirrels are actively taking the bait, the trap is rebaited and the trigger is activated. Walnuts, almonds, oats, barley, and melon rinds are effective trap baits. Another effective trap is the Conibear 110. These traps can be placed in burrow openings so that when squirrels pass through them, they trip the trigger and are captured. As with all traps, take precautions to minimize trapping of non-target wildlife and pets.

Live-traps, such as wire-cage and multiple-capture traps, can also be used to capture ground squirrels. As with box traps, walnuts, almonds, oats, barley, and many fruits and vegetables are all effective baits. Because these traps keep animals alive after capture, they are useful in areas where non-target captures are a concern (e.g., areas with pets, children, etc.). However, ground squirrels must be euthanized by the trapper upon capture as translocation of ground squirrels is illegal.

Pocket gophers.—Trapping is safe and one of the most effective although labor intensive methods for controlling pocket gophers. Nonetheless, the cost and time for application may be offset by effectiveness. Several types and brands of gopher traps are available. The most common type is a two-pronged, pincher trap such as the Macabee, Cinch, or Gophinator, which the gopher triggers when it pushes against a flat, vertical pan. Another popular type is the choker-style box trap, although these traps require extra excavation to place and may be a bit bulky to be practical in a large field setting.

Traps are placed into main tunnels or lateral tunnels. Main tunnels are found by probing near a fresh mound, usually on the side closest to the plug in the mound. The main tunnel is usually 6 to 12 inches below ground; the probe will drop quickly about 2 inches when you find it. Traps are then placed in as many tunnels as are present as you will not know which side the gopher currently is using. Traps should be staked down to ensure that no predators run off with your traps. If there is no evidence that a gopher has visited the trap within 24 hours, the trap may be moved to a new location.

Pincer-type traps can also be placed in lateral tunnels, which are tunnels that lead directly to the surface. To trap in laterals, the plug should be removed from a fresh mound, and a trap placed into the tunnel so that the entire trap is inside the tunnel. Gophers will come to the surface to investigate the lateral tunnel opening and will be caught. This approach is quicker and easier to implement than trapping in the main tunnel. However, trapping in lateral tunnels may be less effective at certain times of the year (e.g., summer) and for more experienced gophers.

Voles.—Trapping is not typically used to control vole populations. Voles can easily be captured with standard mouse snap-traps, but the amount of labor, time, and resources required to remove voles from fields is counter-productive.

Other control approaches

Biocontrol.—This approach relies on natural predation to control rodent populations. From a management perspective, this typically involves the use of owl boxes to encourage owl predation of gophers and voles, or raptor perches to encourage hawk predation of ground squirrels. Unfortunately, no scientific study has ever been able to show that raptors substantially reduce rodent populations in agricultural fields. Raptors do eat a large number of rodents per year, but do so over a wide enough area that they are not able to reduce rodent populations to low enough levels to constitute effective control.

Cultural practices.—Habitat modification is an example of a cultural practice. This approach involves altering rodent habitat to reduce its desirability for that site. This can be a good approach for reducing rodent populations in many situations. For ground squirrels, removal of brush or pruning piles will eliminate preferred burrow locations and can increase overall effectiveness of management programs. Gophers prefer nitrogen-fixing plants and plants with big fleshy taproots. Removing these plants can reduce the habitat potential of a given area for gophers. Likewise, cover removal can greatly reduce, and in some cases eliminate, vole populations given their extreme need for vegetative cover to avoid predation.

Cultivation is another example of an effective cultural practice. If you have a field that you are going to replant, deep ripping will eliminate many of the extant burrow systems and will kill some of the rodents in the process. Destroying the burrow systems helps slow down potential reinvasion into fields, and when combined with an aggressive burrowing rodent control program post-cultivation, can provide a “clean slate” for a newly planted field.

Flood irrigation.—Where still feasible, flood irrigation can help control burrowing rodent populations. When a field is flooded, the rodents must come to the surface or drown. When at the surface, they can be picked off by a number of predators; growers and their dogs can also actively seek out rodents at this time to further reduce populations of these damaging pests.

Gas explosive device.—This is an instrument that injects a mixture of propane and oxygen into the burrow system and then ignites this mixture thereby potentially killing the burrowing rodent through a concussive force. This approach has the added benefit of destroying the burrow systems which should slow down reinvasion rates by burrowing rodents. However, initial studies have not shown it to be overly effective for ground squirrels or gophers. Additionally, there are potential hazards associated with this device including damage to buried pipes and cables, injury to the user, and the potential to catch things on fire. Additionally, these devices are quite loud; as such, they are not practical for use in or around residential areas.

Repellents.—No scientific data has been reported to show that current chemical repellents effectively keep rodents from inhabiting fields although a new repellent designed for use in irrigation tubing has yet to be thoroughly tested. I hope to test it in the near future. Frightening rodents with sound or vibrations also does not appear to be effective.

Efficacy of Fluopyram on *Monilinia* spp., *Rhizopus stolonifer* and carboxamide resistant *Alternaria alternata*

J. Alfonso Cabrera, Research Plant Pathologist, Western Field Technology Station, Bayer CropScience, 266 S. Monroe Ave. Fresno, California 93706. E-mail: alfonso.cabrera@bayer.com

George Musson, Product Development Manager, Fungicide Development North America, Bayer CropScience, 2 T.W. Alexander Drive, Research Triangle Park, North Carolina 27709. E-mail: george.musson@bayer.com

Introduction

In California the fungi *Monilinia* spp. and *Rhizopus stolonifer* cause hull rot in almonds. These fungi are able to cause significant yield losses because both invade hulls and produce a toxin that can kill the shoot attached to the fruit. As consequence, other green fruit on the same shoot don't mature and remains on the tree after harvest. The disease causes dieback of shoots and fruiting wood that reduce productivity in future years (UC IPM, 2002; 2012). *Alternaria alternata* is a fungus that causes the leaf spot disease and defoliation in almond trees of California. June and July are the months where leaf spots develop most rapidly, and trees can be almost completely defoliated by early summer when the disease is severe (UC IPM, 2002; 2012). To adequately control *Monilinia* spp., *Rhizopus stolonifer* and *Alternaria alternata* chemical control measures are often required. However, in California there are *Alternaria alternata* strains that are resistant to carboxamide fungicides like Boscalid (Avenot and Michailides, 2007; Avenot et al., 2008). Therefore, chemical options that can control all three different fungi including carboxamide-resistant strains are of current interest.

Fluopyram is a novel systemic fungicide which acts as a succinate dehydrogenase inhibitor (SDHI) and is classified as a member of fungicide resistance action committee (FRAC) Group 7. Fluopyram is not a carboxamide. It is uniquely in the Pyridinyl-ethyl-benzamide chemical group. It shares the same mode of action with carboxamides Boscalid and Penthiopyrad, but it behaves very differently. Fluopyram in combination with Trifloxystrobin is commercially available as LUNA[®] SENSATION (21.4% of Fluopyram & 21.4% of Trifloxystrobin). LUNA[®] SENSATION is demonstrating a different resistance pattern than other SDHI fungicides. LUNA[®] SENSATION is registered for use on almonds (and other crops) in California (CDPR, 2012).

In this investigation, the performance of LUNA[®] SENSATION against different almond pathogens in California was evaluated. The objectives of the study were to i) determine the efficacy of LUNA[®] SENSATION on hull rot (*Monilinia* spp. and *Rhizopus stolonifer*) and ii) evaluate the activity of LUNA[®] SENSATION on carboxamide resistant *Alternaria alternata*.

Materials and Methods

Field trials were performed by Dr. Jim Adaskaveg (Department of Plant Pathology and Microbiology, University of California, Riverside), Dr. Steve Deitz (Sawtooth Ag Research) or Bayer CropScience personnel throughout California in 2009 and 2011. Generally the trials were set up in a complete randomized block design and three or four repetitions per treatment were performed. Chemical treatments were applied with an air-blast sprayer at generally 100 gal/acre. A treatment was left unsprayed to serve as control in each trial.

For hull rot evaluations 3 field trials were performed using the almond cultivar Nonpareil. One trial was performed in Colusa, another trial was performed in Stanislaus, and the other in Fresno. In the Colusa trial, LUNA[®] SENSATION (5 oz /acr), Quash (3.5 oz/acr), or Quadris Top (14 oz/acr) were applied. Spraying was performed either at early suture, 20% split or at both times. In the Stanislaus trial, LUNA[®] SENSATION (5 oz/acr), Ph-D 11.2DF (6.2 oz/acr), Quash (3.5 oz/acr), or Inspire Super + NIS (20 oz/acr) were applied twice; at early and 20% split. In Fresno trial, 2 applications of LUNA[®] SENSATION (4.1 or 7.6 oz/acr) at early hull split were performed. The hull rot incidence (%) caused by both *Monilinia* spp. and *Rhizopus stolonifer* was evaluated at harvest.

For *Alternaria alternata* evaluations 2 field trials were performed using the almond cultivar Monterey. *In vitro* sensitivity of isolates of *Alternaria* spp. from almonds tested with Boscalid showed that some of the isolates used in the present investigation were resistant to carboxamide. One trial was performed in Kern county and the other in Tulare. The treatments in Kern trial consisted in LUNA[®] SENSATION (4 oz/acr), Syllit 3.4FL (48 fl oz/acr), Quash 50WG (4 oz/acr), Inspire Super SC (14 fl oz/acr), Adament 50WG (6 oz/acr), and Pristine 38WG (14.5 oz/acr). Three sprays of each chemical were performed, one in May and two in June. In Tulare county trial, the treatments were LUNA[®] SENSATION (4 oz/acr), LUNA[®] SENSATION (5 oz/acr), Adament 50WG (6 oz/acr), and Pristine 38WG (14.5 oz/acr). In this trial 5 sprays were performed from spring to summer. In these trials, disease incidence on leaves (60 leaves/rep), disease severity on leaves, and tree defoliation was evaluated.

The data obtained in each trial was subjected to one-way analysis of variance. When significant differences were detected ($p < 0.05$), Fisher's last significant difference test (LSD) was performed at 95% of interval of confidence.

Results and Discussion

In Colusa trial, LUNA[®] SENSATION performed better than Quadris Top controlling hull rot disease (Table 1). Quash applied at 20% split had similar hull rot incidence than the untreated control, whereas LUNA[®] SENSATION provided a significant control. Application of LUNA[®] SENSATION at early suture was key to provide excellent control of the hull rot disease. In Stanislaus trial, LUNA[®] SENSATION was the only fungicide treatment that provided significant control of hull rot (Table 2). The hull rot incidence in the other fungicide treatments which use

Ph-D 11.2DF, Quash, and Inspire Super + NIS was not different than that in the untreated control. In Fresno trial, increasing the rate of LUNA[®] SENSATION enhanced the hull rot control activity (Figure 1).

Table 1. Effect of different fungicide treatments on hull rot incidence in almonds cv. Nonpareil in Colusa, California

Treatments	Application	Application	Hull Rot Incidence (%)	LSD
	Early Suture	20% split		
Control			16.8	a
Quadris Top 14 oz	@		10.5	a
Quadris Top 14 oz		@	14.25	a
Quadris Top 14 oz	@	@	20.5	a
Quash 3.5 oz	@		9.25	b
Quash 3.5 oz		@	10.5	ab
Quash 3.5 oz	@	@	6.5	b
Luna Sensation 5 oz	@		4.5	b
Luna Sensation 5 oz		@	4.75	b
Luna Sensation 5 oz	@	@	5.5	b

Table 2. Effect of different fungicide treatments on hull rot incidence in almonds cv. Nonpareil in Stanislaus, California

Treatments	Percent Hull Rot incidence	LSD
Control	72.9	a
Ph-D 11.2DF 6.2 oz	67.0	a
Quash 3.5 oz	60.3	a
Inspire Super + NIS 20 oz	70.0	a
Luna Sensation 5 oz	42.8	b

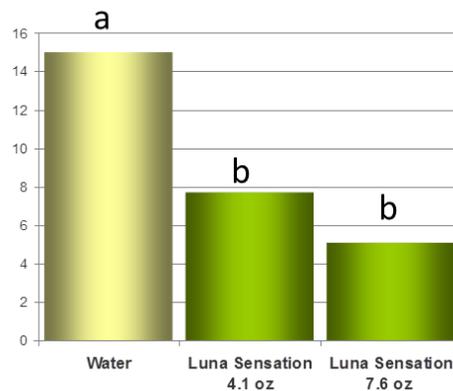


Figure 1. Effect of 2 applications of LUNA[®] SENSATION at 4.1 or 7.6 oz/acr at early hull split on hull rot incidence in almonds cv. Nonpareil in Fresno, California

In Kern trial, LUNA[®] SENSATION substantially reduced *Alternaria alternata* incidence on the leaves (Table 3). Syllit 3.4FL and Adament 50WG treatments had similar disease incidence than the untreated control according to LSD analysis. The severity of *Alternaria alternata* was reduced by LUNA[®] SENSATION. Additionally, LUNA[®] SENSATION provided an excellent control of tree defoliation caused by *Alternaria alternata*. In Tulare trial LUNA[®] SENSATION at 5 oz/acre provided the highest control of tree defoliation over LUNA[®] SENSATION at 4 oz/acre, Pristine, and Adament (Figure 2).

Table 3. Effect of different fungicide treatments on *Alternaria alternata* in almonds cv. Monterey in Kern, California

Treatments	Incidence on leaves (%)	LSD	Severity (lesions/leaf)	LSD	Tree defoliation (rating 0 - 4)	LSD
Control	92.8	a	2.46	a	2.53	a
Syllit 3.4FL (48 fl oz/acr)	87.1	ab	1.68	bcd	1.46	bc
Quash 50WG (4 fl oz/acr)	63.1	efgh	0.84	ghijk	0.92	de
Inspire Super SC (14 fl oz/acr)	78.3	bcd	1.43	cdef	0.88	de
Adament 50WG (6 oz/acr)	83.4	ab	1.71	bc	1.25	bcd
Luna Sensation (4 oz/acr)	63.1	fgh	0.92	ghijk	0.5	efgh
Pristine 38WG (14.5 oz/acr)	76.9	bcdef	1.48	bcde	1.21	bcd

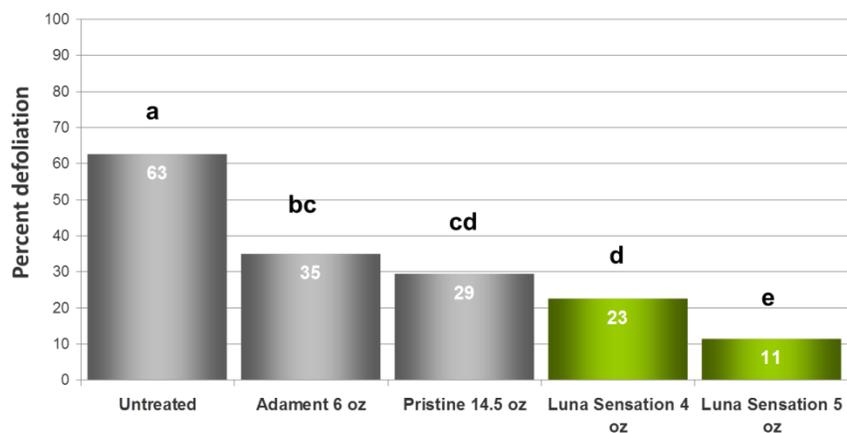


Figure 2. Effect of different fungicide treatments on tree defoliation caused by *Alternaria alternata* in almonds cv. Monterey in Tulare, California

The mixture of Fluopyram and Trifloxystrobin (LUNA[®] SENSATION) was very effective against both *Monilinia* spp. and *Rhizopus stolonifer* reducing the hull rot incidence in almonds. Application of LUNA[®] SENSATION at early suture (5 oz/acre) was essential to provide excellent control of the hull rot disease. LUNA[®] SENSATION applied two times, at early split and 20% split (5 oz/acre each time), provided better control of the hull rot disease than other fungicides tested. Three applications of LUNA[®] SENSATION reduced tree defoliation, the disease incidence and severity caused by *Alternaria alternata* in fields where carboxamide-resistant strains were present. Tree defoliation can be substantially reduced by application of LUNA[®] SENSATION, in particular in a 5 application program which provided a better *Alternaria alternata* control than Pristine. Increasing LUNA[®] SENSATION from 4 oz/acre to 5 oz/acre increased the tree protection against defoliation caused by *Alternaria alternata*. In conclusion, LUNA[®] SENSATION had an excellent fungicide performance against two major almond diseases throughout different counties of California in several almond cultivars and in different years of testing.

References

Avenot, H. F., and T. J. Michailides. 2007. Resistance to boscalid fungicide in *Alternaria alternata* isolates from pistachio in California. *Plant Dis.* 91:1345-1350.

Avenot, H. F., D. P. Morgan, and T. J. Michailides. 2008. Resistance to pyraclostrobin, boscalid and multiple resistance to Pristine (pyraclostrobin+ boscalid) fungicide in *Alternaria alternata* causing alternaria late blight of pistachios in California. *Plant Pathol.* 57:135-140.

California Department of Pesticide Regulation (2012). URL:
<http://cdpr.ca.gov/docs/label/prodnam.htm> (accessed on December 4, 2012).

University of California, Statewide Integrated Pest Management website. (2012). URL:
<http://www.ipm.ucdavis.edu/PMG/selectnewpest.almonds.html> (accessed on December 4, 2012).

University of California, Statewide Integrated Pest Management (2002). Almonds, second edition. Division of Agriculture and Natural Resources, Publication # 3308. Pp. 199.



American Society of Agronomy

California Chapter

**Session II
Innovative Dairy
Technologies**

**Session Chairs:
Dave Goorahoo
Danyal Kasapligil**

Greenhouse Gas Measurements at a Central California Dairy

Alam Hasson, Chemistry Department, California State University, Fresno
2555 E San Ramon Avenue, Fresno, CA 93740
Phone (559) 278-2420, ahasson@csufresno.edu

Segun Ogunjemiyo, Geography Department, California State University, Fresno,
2555 E San Ramon Avenue, Fresno, CA 93740
sogunjemiyo@csufresno.edu

Shawn Ashkan, Center for Irrigation Technology
5370 N Chestnut Avenue, Fresno, CA 93740
sogunjemiyo@csufresno.edu

Dairy facilities are thought to be significant sources of greenhouse gases (GHG), but emissions data for facilities in California are currently lacking. In this work, emissions of methane and carbon dioxide were measured from a commercial facility in Central California. GHG concentrations were monitored using a combination of techniques (infra-red photoacoustic detection, diode laser absorption spectroscopy and gas chromatography with flame ionization detection). Emissions were determined using two approaches. First, flux isolation chambers were used to measure emissions directly from specific on-site sources. Second, ambient concentrations were measured upwind and downwind of the facility at heights up to 60 m above ground level using tethered weather balloons. Emissions were then calculated by fitting observed GHG concentrations to the output of a backwards trajectory stochastic Lagrangian model and a Gaussian steady-state plume model. Preliminary results from these measurements and their implications will be presented.

NOTES & QUESTIONS

A Systems Approach to Conservation Tillage of Forage Crops: A California Dairyman's Perspective

Dino Giacomazzi

Dairy Farmer & UC Conservation Agriculture Systems Innovation (CASI)

Hanford, CA.

Cell: 559.381.8125

dino@giacomazzi.us

www.dinogiacomazzi.com

@dairydino

The following document is an excerpt from an article in the *California Tillage Newsletter Technology Review Manual, Volume 001*, provided with the kind permission of the presenter.

Complete copy of the newsletter is available online at:

http://www.suscon.org/conservationtillage/pdfs/SusCon_DinoTillageBroc_M6_SinglePages.pdf

Introduction

Since 1893 my family has been farming and milking cows in Hanford, CA. When my great grandfather purchased this land it was nothing but sagebrush, coyotes, and alkali soil. Back in those days, in order to develop the land they used a technique of deep ripping and flood irrigation to leach the salts down past the root zone to create usable topsoil. Since my great grandfather, grandfather and father milked cows in addition to farming; they had the added benefit of using manure as fertilizer. By using the technology and information available at the time, my ancestors were able to transform nonproductive soil into some of the most fertile land in the Central Valley of California. My story picks up where they left off.

In 2002 after spending 10 years off the farm I returned to the family business. During those years I had been working with computers and learned that when you start a new project it is important to begin with the most current information and technology. So when I started farming I wanted to see what the state of farming looked like at that time. During the process of doing my research, my father applied for an NRCS grant for a reduced tillage program. In order to comply with the terms of the grant, we had to find ways to reduce the number of passes in the field to mitigate transient dust issues. This led to a study of the different technologies and practices available for conservation tillage.

The following information is the result of 8 years of research and practice in conservation tillage. This information represents my current understanding of the system and the practices that work for my specific situation. Like all farming, things are constantly changing and every practice does not work for every field. So please consider this a guide to help you get started. My hope is that you can start with this document as the current state of CT technology and grow it from here on your own. Good luck.

Systems Approach

One of the most important lessons I've learned in the development of a CT program is that you must develop a system. If you look at implementing individual practices, such as strip tilling, without considering other changes in your program, it is unlikely you will be successful. I have seen many farmers replace conventional corn practices with strip-till without considering how they are going to manage nutrients and weeds. This lack of planning usually leads to less than desirable outcomes. The farmer usually gets discouraged and develops a belief that CT doesn't work. If you are willing to spend a little time learning the systems of CT you will be successful. In my personal experience, once I had developed a system that worked, every new field I transition to CT actually shows an increase in yield the first year. In fact, all of my CT fields are out performing my conventional fields in yield and quality.

As I tried different practices it was necessary to develop some criteria as a basis for evaluating them. I had to have a way to quantify the value of a piece of equipment, practice, or technique so I developed the following criteria. A CT system must:

1. **Be economically sustainable** — I have always had the attitude that helping the environment **MUST** be profitable. There is no reason to sacrifice success in order to achieve sustainability and be a good steward of the land, water, and air. Therefore, the CT system must be profitable. Not only must it be profitable, it must be more profitable than my conventional system. This is called progress. Every businessperson wants to streamline in order to become more efficient and profitable, it's what drives us. If you are interested in changing the world for the better, make the change you seek the profitable thing to do.
2. **Increase yield** — Planet Earth has a finite carrying capacity. That is the planet's ability to provide food for the species roaming around on it. There have been several studies of the Earth's carrying capacity and the results range from 2.5 to 15 billion people, depending on technology. I'm not sure what the actual number is, but I do know that in order to feed a growing population on a shrinking amount of productive land we must constantly strive to increase yield and nutrient density. In my opinion, every farmer has an obligation to live by a Hippocratic oath of sorts to do more with less.
3. **Improve soil quality** — My great-grandfather started working this land more than a century ago and his goal was to improve soil quality in order to feed his family. My goal is to leave this farm to my son in better shape than I found it, which was pretty darn good. Any component of the system must promote balance in biological entities like microbes and earthworms, minerals, nutrients, oxygen, water, and organic matter.
4. **Reduce inputs** — The system must reduce inputs including tractor passes, diesel, equipment to own and maintain, fertilizer, pesticides, labor, and water. Remember that **EVERY** input costs you money. The goal of the CT program is to become more profitable while conserving resources and taking care of the environment.
5. **Reduce emissions** — The primary environmental benefit of CT is reduction of emissions. The CT system must reduce particulate matter (dust), VOC's (smog), and now carbon is coming into this equation. This whole carbon racket is a good example of my earlier statement

of environmental solutions must be profitable. As a farmer I think it is a good idea to sequester carbon in the soil, because it's good for the soil and the plants. The government seems to think that despite being the most abundant element in the universe, carbon is a pollutant. I believe carbon has more value in the ground than in the air, so it is in my interest to sink as much of the stuff as I can in the soil. This has nothing to do with the climate.

The System

In order to explain my CT system it is necessary to understand my conventional program. The following Table 1 describes the difference in passes between my conventional program and my CT program. Currently my CT program is performed exclusively on double-cropped dairy forage. We grow wheat in the winter and corn in the summer. The following outlines the tractor passes for each program.

Table 1: Conventional Passes vs. CT Passes

Conventional Tillage	Conservation Tillage
<p>Wheat to Corn</p> <ol style="list-style-type: none"> 1. Rip / Chisel 2. Disk 3. Disk 4. Lister / Disk Bedder <p>Pre-Irrigate</p> <ol style="list-style-type: none"> 5. Cultivate Beds 6. Cultivate Beds 7. Roll Beds 8. Plant into moisture 9. Cultivate Corn 10. Cultivate Corn 11. Side Dress Fertilizer 12. Spray Miticide w/ Roundup <p>Corn to Wheat</p> <ol style="list-style-type: none"> 13. Spread Composted Manure 14. Disk 15. Disk 16. Drill wheat 17. Spray Herbicide by Air 	<p>Wheat to Corn</p> <ol style="list-style-type: none"> 1. Strip Till <p>Pre-Irrigate</p> <ol style="list-style-type: none"> 2. Plant with on-seed and banded fertilizer 3. Spray herbicide 4. Spray Miticide and herbicide <p>Corn to Wheat</p> <ol style="list-style-type: none"> 5. Spread Composted Manure 6. Disk 7. No Till Drill 8. Herbicide Spray by ATV

Net Pass Reduction for CT System

<p>Conventional Tillage</p> <p>11 Dirt moving passes / year</p> <p>Vs</p> <p>Conservation Tillage</p> <p>1 strip till (partial dirt moving)</p> <p>1 disk (complete dirt moving)</p> <p>= Net reduction of 9.5 dirt moving passes per year.</p> <p>87% reduction in field passes</p>

Manure Management for Solid and Liquid Manure Nitrogen Application

Ben Nydam

Dellavalle Laboratory, Inc.

Cell: 559-647-5331

e-mail: bnydam@dellavallelab.com

Please feel free contact **Ben Nydam** for additional information related this presentation.

NOTES & QUESTIONS



American Society of Agronomy

California Chapter

Session III
Plant Nutrition

Session Chairs:
Rich Rosecrance
Mary Bianchi

Tracking Nutrient Budget Trends using NuGIS

Robert Mikkelsen, Director, Western North America
International Plant Nutrition Institute
4125 Sattui Ct, Merced, CA 95348
Phone (209) 725-0382, rmikkelsen@ipni.net

Introduction

There are very few “ideal” soils in the world- that is, soils that contain all of the essential nutrients in the proper balance required by crops. Overcoming these pre-existing nutrient deficiencies is the goal of the fertilizer industry. While animal manures are excellent at providing many of the essential nutrients for crops, their composition is rarely in balance with what the soil requires to adequately supply the plant’s needs. Similarly, legume cover crops are good N source for subsequent crops, but provide no other additional nutrients that were not already in the soil.

It is in everyone’s best interest to utilize nutrients as efficiently as possible. However, accomplishing this goal- or even defining it- is difficult to achieve. In general, getting as much of a nutrient into the harvested portion of a crop is the concept of efficient nutrient use. Tracking the recovery of applied nutrients is a key component to measuring nutrient efficiency.

With the interest in N management for water quality protection, there is growing reliance on nutrient budgets as an indicator of environmental stewardship.

NUTRIENT BUDGETS

The generally accepted approach to nutrient balance measures the difference between nutrient inputs and outputs in an agricultural system. Nutrient or mineral balances establish a link between agricultural nutrient use, changes in environmental quality, and the sustainable use of soil nutrient resources. Depending on the data input, nutrient budgets can be used at a variety of scales.

Nutrient budgets are becoming increasingly common as a tool to describe nutrient flows within farming systems and to assist in the planning of the complex spatial and temporal management within rotational cropping and mixed farming systems.

Budgets are the outcome of a nutrient accounting process, ranging from simple to complex, which details all the inputs and outputs to a given system over a fixed period of time. The underlying assumption of a nutrient budget is that of mass balance (i.e. nutrient inputs to the system minus any nutrient exports equal the change in storage within the system (Meisinger and Randall, 1991).

Many approaches have been used to estimate nutrient balances, depending on the intended purpose. For example, the techniques appropriate for developing national, regional, or global estimates of efficiency are much different from a field-scale or micro-plot approach. Additionally, a nutrient deficit or surplus over the short term does is not immediately indicative

of undesirable consequences, but in fact may be beneficial and desirable for building overall soil fertility.

Several basic techniques are used to measure nutrient balances- all of which have various limitations depending on the level of measurement and the availability of data. The usefulness and reliability of any type of budget depends on its completeness. The three main approaches are:

Soil Surface Balance: This approach measures the difference between the inputs (or the application) of nutrients and the output (or removal of nutrients) from the soil. While this budget provides the most detail for nutrient management planning, there is usually uncertainty associated with the data inputs and the partitioning of the components of the nutrient balance between air, soil, and water. An example:

“Sheldrick et al (2002) conducted a nutrient balance for 197 countries using the soil surface balance technique. Working at a national level allowed them to use the FAO data base, which contains detailed information related to crop and livestock production, as well as fertilizer consumption statistics.

They reported that nutrient efficiency is approximately 50% for N, 40% for P, and 75% for K. In a few countries (Western Europe, Japan, and Rep. of Korea) there is a surplus of these primary nutrients. However, in many other countries, food production is currently depending on depleting large quantities of nutrients from soil reserves and this unsustainable trend is likely to continue into the future. The world average soil depletion of nutrients was estimated to be 10 lb N/A, 9 lb P₂O₅/A, and 21 lb K₂O/A. They concluded that the current depletion of K is particularly severe and could ultimately lead to a serious loss of crop production in several countries.

Farm Gate Balance: This type of balance simply measures the difference between the nutrient content of farm inputs and the nutrient content of farm outputs. This balance has been successfully used for P and K, but it ignores many of the complex on-farm transformations that N is subject to (e.g. NH₃ volatilization, denitrification, volatile losses during crop senescence, etc.). This method quantifies nutrients supplied to and removed from the farm, but does not quantify the nutrients circulating within the farm enterprise. This type of budget is easy to construct and requires relatively little data, it is consequently used widely for policy analysis. An example:

Nelson and Mikkelsen (2005) constructed a P budget for a typical swine farm in North Carolina to examine the potential nutrient accumulation patterns and make predictions of future trends. They measured the nutrient content of all feed and piglets entering the farm. They subtracted the P in the mature hogs, animal mortalities, and crops leaving the farm. The difference between imports (30,664 lb P/yr) and exports (13,633 lb P/yr) indicates an average accumulation of 17,030 lb P/yr on this particular farm. This type of analysis can be used for making farm-level nutrient management plans and regional estimates of nutrient use.

Soil System Balance: This approach is commonly used where detailed information on inputs, outputs, and internal transformations is available for all the important components. This type of

balance requires much larger data inputs than the previous approaches, but the use of relevant computer models can help with parameter estimates when field observations are not available.

A number of excellent mechanistic models have been developed to trace the fate of nutrients. The use of isotopes (e.g. ^{15}N) to trace the behavior of applied fertilizer has also been very useful in understanding the complex physical/chemical/and microbial transformations that occur after nutrients are added to soil. The commonly used models operate at different scales (from global to micro-plot scale) and this scale issue must be considered when choosing the most appropriate model for a specific nutrient balance.

Nutrient Use Geographic Information System (NuGIS)

IPNI (2012) recently conducted a survey of plant nutrient use and removal which was compiled within a GIS for each county in the United States. The on-line tool (nugis.ipni.net) shows the partial nutrient balance derived from data on fertilizer use, animal manure, and nitrogen fixation. This was compared with nutrient removed in harvested crops. The search parameters are selected by the user (the nutrient, time period, geographic region) and interactive maps are produced.

In order to make consistent comparisons across space and time, we selected years for our analysis where data were available from each source with some degree of consistency in reporting. Data were obtained for 5-year periods, coinciding with the USDA Census of Agriculture from 1987–2007. The nutrient input, removal, and acreage values calculated for the portions of each county were summed by watershed to produce input, removal, and acreage data at the watershed scale. Nutrient Balances, Removal to Use Ratios, and Balances per Cropland Acre were then recalculated using this watershed scale data. This partial nutrient balance does not account for atmospheric deposition, biosolids application, or nutrients contained in irrigation water. It does not account for nutrient losses other than crop removal (such as leaching, erosion, or volatilization). This tool allows the user to select regions of the United States that are of particular interest.

A national view reveals that nutrient “Removal to Use” ratios appear unsustainably high in some regions and unsustainably low in others. It highlights the need for more intensive monitoring of soil nutrients and improved nutrient management.

REFERENCES:

IPNI. 2012. A Nutrient Use Information System (NuGIS) for the U.S. Norcross, GA. Available on line >www.ipni.net/nugis<

Meisinger, J.J., and G.W. Randall. 1991. Estimating nitrogen budgets for soil-crop systems. p. 85–124. *In* R.F. Follett et al. (ed.) *Managing nitrogen for groundwater quality and farm profitability*. ASA, CSSA, and SSSA, Madison, WI.

Nelson, N.O., and R.L. Mikkelsen. 2005. Balancing the phosphorus budget of a swine farm: A case study. *J. Natural Resources and Life Sci. Educ.* 34:90-95.

Sheldrick, W.F., J.K. Syers, and J. Lingard. 2002. A conceptual model for conducting nutrient audits at national, regional, and global scales. *Nutrient Cycling Agroecosystems.* 62:61-72

Best Management Nutrient Practices for Nut Crops

Robert H. Beede, Farm Advisor, University of California Cooperative Extension, Kings and Tulare Counties, 680 N. Campus Drive., Suite A, Hanford, CA 93230
Phone (559) 582-3211, ext 2730 FAX (559) 582-5166 bbeede@ucdavis.edu

Patrick H. Brown, Professor, Plant Sciences Department, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752- 0902 phbrown@ucdavis.edu

Craig Kallsen, Farm Advisor, University of California Cooperative Extension, Kern County
1031 South Mount Vernon Avenue, Bakersfield, CA 93307
Phone (661) 868-6200 FAX (661) 868-6208 cekallsen@ucdavis.edu

Introduction

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

Factors Affecting the Nutrient Supply to the Plant

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

Soil factors such as soil type and texture, soil moisture, pH and soil depth, as well as plant factors including root distribution and density, rootstock, fruit load and shoot growth, all

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

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

Amendments intended to change pH or improve soil structure can influence nutrient availability to the plant. However, it is essential that all aspects of the orchard and the production system be considered before deciding on such a course of action. The most common and effective soil amendment, gypsum, is composed of calcium sulfate whose solubility is such that it provides large amounts of free calcium to aggregate soil particles for improved infiltration, as well as aid in calcium nutrition for the plant.

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

Soil analysis

Soil analysis provides information on nutrient content and the soil chemistry affecting its availability. Cation exchange capacity (CEC, the ability of a soil to retain cations for subsequent release into the soil solution), pH, and salinity all affect the availability of nutrients present in the soil. It is **CRITICAL** that adequate soil analyses be performed **PRIOR** to orchard establishment for accurate assessment of the site for nut crops. **These samples are directly, and almost exclusively, focused on the salinity characteristics of the soil. High salinity must be corrected prior to planting to avoid poor orchard performance and tree loss.** Other soil chemical conditions, such as high pH combined with high soil lime (calcium carbonate) limit zinc, iron, manganese, and copper availability. The saturation percentage (SP) can also be used as a general guide to soil texture and water holding capacity. Pre-plant soil assessment often reveals chemical or physical conditions unsuitable for tree crops and thus saves the investor from serious financial loss. Note that **soil analysis is NOT used exclusively as the guideline for fertilization**, but principally for the assessment of soil chemical conditions which limit the growth of future and existing nut crops.

Established orchards benefit from soil analysis by assessing the impact of fertilization and irrigation management. Monitoring trends in soil nitrate-nitrogen concentration within the root

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

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

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

Interpretive guides for soils

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

Recent research on the effects of salinity in pistachio indicates it has significantly greater salt tolerance than other nut crops. The recommended thresholds are changing, since a new project is being conducted on young trees by UC Farm Advisor, Blake Sanden. It is presently recommended that the EC_w (Electrical Conductivity) of the irrigation water should not exceed 5.0 dS/m for the establishment of young trees and long term production. The EC_e (electrical conductivity of the saturation extract) of the soil should be 6.0 dS/m (at 25⁰ C) or less. Soil chloride (Cl) and sodium (Na) in excess of 50 meq/liter were tolerated on mature trees, but these levels are still under evaluation for developing orchards. Experience in saline areas on the Westside of the San Joaquin Valley suggests pistachios tolerate 20-30 meq/l of Na and Cl and up to 4 ppm Boron (B) in the soil without adverse impacts on yield. Pistachios may be tolerant of exchangeable sodium percentages (ESP) as high as 25% short term if the average soil EC_e is less than 6, and calcium amendments are employed. ESP levels near 15% are recommended for long term production. High exchangeable sodium levels in the surface soil can cause structural deterioration (soil particles repel one another and reduce the air space for water movement) and subsequent water infiltration problems. Hence, water stress can be an indirect but significant effect of high soil sodium levels in the surface soil.

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

Plant analysis

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

Sampling procedure and interpretation

Concentrations of leaf nutrients vary with time, leaf age, position in canopy and the presence or absence of fruit. Trees within an orchard may also vary in their nutrient status as a result of differences in soil fertility, water availability or light exposure. Therefore, it is essential that

sampling techniques be standardized if valid comparisons are to be made. **Choice of sampling method also varies depending on the purpose of the survey.** If the aim is only to identify the problem in an isolated tree or area, then sampling just a few poor and some good trees should suffice. If a determination of overall nutrient status in a large orchard is required, then more extensive sampling of trees from many sites will be required.

The correct leaf sampling procedure differs slightly by nut commodity. For pistachios, fully expanded sub-terminal leaflets (pistachios typically have five leaflets per compound leaf) are randomly collected from **non-fruiting branches** at about six feet from the ground. Four to ten leaves are typically collected per tree, and 17 trees are sampled in each orchard block, with each tree 25 yards apart. **Leaves sprayed with micronutrients typically cannot be analyzed for that nutrient since the surface contamination cannot be removed.** Hence, leaves having received in-season nutrient sprays for the elements of interest should either not be sampled, or one must ignore the results for micronutrients represented in the spray and at very high levels in the analysis. One can also wait sufficiently long after treatment to allow for some new growth to test for such elements as zinc. Orchards with specific micronutrient problems may even justify the labor required to temporarily bag shoots prior to a nutrient spray for sampling at a later date. The challenges associated with acquiring an accurate tissue samples re-enforce the value of visual nutrient symptom assessment, especially in the case of zinc, copper, boron, and nitrogen. Samples should be kept in labeled **paper** bags and submitted to the analytical service within 24 hours of collection. Leaves are living organs! Keep them cool, and process them promptly! Pistachios are sampled from late July through August. The pistachio critical levels established through experimentation and observations (Table 1) are based on this timing. However the comparison of good trees against poor ones can be done at any time. Samples collected at times other than from late July through August may have nutrient concentrations different than those recommended in the critical values table and must be interpreted with care. Laboratories often have sufficient sampling history at different growth stages to assist in interpreting nutrient levels taken earlier in the season, when correction can have the greatest value for the current crop.

For **walnuts**, the least change in leaf nutrient concentration occurs between late June and early July. The sample date is different from pistachio due to the large boron requirement of pistachio, which continues to rise in the leaf tissue until nut maturity. Walnut nutrient studies performed over decades by UC researchers have examined leaves, petioles, hulls, nuts, stems, and even bark as the basis for critical level establishment. It was determined that fully expanded leaves from spurs were the most reliable. **No designation is presently made between selection of fruiting over non-fruiting walnut spurs.** Select spurs from as high as possible, but at least six feet off the orchard floor. Each sample should consist of about 50 leaflets (a walnut leaf contains three to five leaflets on a single petiole or stem). Do not sample from trees in just one area, unless it appears to have a specific problem. Critical and adequate tissue levels for July can be found in Table 2.

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

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

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

Element	Critical Value	Suggested Range	Reference
Nitrogen (N)	1.8%	2.2 -2.5%	Weinbaum, et.al. 1988, 1995
Phosphorus (P)	0.14%	0.14-0.17%	
Potassium (K)	1.6%	1.8 - 2.0 %	Brown, et.al. 1999
Calcium (Ca)	1.3% (?)	1.3-4.0%	
Magnesium (Mg)	0.4%	0.6-1.2%	Brown, et.al. 2012
Sodium (Na)	(?)	(?)	
Chlorine (Cl)	(?)	0.1-0.3%	
Manganese (Mn)	30 ppm	30-80 ppm	
Boron (B)	90 ppm	150-250 ppm	Uriu,1984; Brown, et.al.,1993
Zinc (Zn)	7 ppm	10-15 ppm	Uriu and Pearson.1981, 1983,1984,1986
Copper (Cu)	4 ppm	6-10 ppm	Uriu, et.al. 1989

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

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

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

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

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

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

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

Interpreting leaf analyses

Results of tissue analysis are reported as the concentration of a nutrient on a dry weight basis. For **macronutrients**, concentrations are reported on a percent basis (grams of nutrient per 100 g dry weight), while **micronutrients** are reported in parts per million (microgram nutrient per gram dry weight). For each element, the laboratory will usually identify the ‘Critical Value’ (CV), or the ‘Adequate Range’ to aid in interpretation of the results. ‘Critical Value’ or ‘Critical Level’ refers to the nutrient concentration at which plant yield is estimated to be at 95% of maximum, or at which distinct symptoms of deficiency are present. Tissue nutrient concentrations below this level will result in poor plant growth and reduced yields. The ‘Adequate Range’ refers to the nutrient concentration range at which growth is optimal. Above this nutrient concentration, plant growth may be inhibited by certain nutrients such as Boron and Chloride, which burn plant tissue at high levels. There is no correlation between macronutrient concentrations above

the adequate level and increased plant performance. In fact, several studies have shown predisposition to diseases and poor fruit quality with abnormally high nitrogen levels. Excessive nitrogen in the plant tissue is also indicative of soil applications which exceed demand and plant uptake capacity. The excess and highly mobile nitrogen can then be easily leached beyond the root zone and into precious groundwater. Excessive potassium fertilization is quickly bound to soil particles electrostatically, so leaching is not a concern. Over application of potassium is also less likely due to its high cost. Critical values are crop specific. It is essential that the nutrient recommendations supplied by the testing laboratory reflect comparison to the adequate and critical values for the nut crop in question, since nutrient requirements differ significantly between crops. This is especially true for pistachio, since it has a much higher boron and potassium requirement than other deciduous tree crops and also tolerates more salinity.

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

Literature Cited

1. Beede, R.H., Padilla, J., and D. Thomas. 1991. Foliar boron and zinc nutrition studies in pistachio. 1991. In: Calif. Pistachio Ind. Ann. Rpt. 1991. pp. 121-126.
2. Brown, P., Ferguson, L. and Geno Picchioni. 1993. Boron nutrition of pistachio: Final report. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 57-59.
3. Brown, P., Zhang, Q., and Bob Beede. 1993. Effect of foliar fertilization on zinc nutritional status of pistachio trees. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 77-80.
4. Brown, P., Zhang, Q., and Bob Beede. 1996. Foliar spray applications at spring flush enhance zinc status of pistachio trees. In: Calif. Pistachio Ind. Ann. Rpt. 1996. pp. 101-106.
5. Brown, P., Zhang, Q., Huang, Z. Holtz, B., and Craig Hornung. 1999. Agronomic and economic responses of mature 'Kerman' pistachio trees to potassium applications in California. In: Calif. Pistachio Ind. Ann. Rpt. 1999. pp. 84-85.
6. Reisenauer, H.M., Quick, J., Voss, R.E., and A. L. Brown. 1983. Chemical Soil Tests for Soil Fertility Evaluation. In: Soil and Plant Tissue Testing in California. University of California Press. Bull. 1879. pp. 39-41.
7. Uriu, K., and J. Pearson. 1981. Diagnosis and correction of nutritional problems. In: Calif. Pistachio Ind. Ann. Rpt. 1981. pp. 30.

8. Uriu, K., and J. Pearson. 1983. Diagnosis and correction of nutritional problems, including the crinkle leaf disorder. In: Calif. Pistachio Ind. Ann. Rpt. 1983. pp. 79.
9. Uriu, K., and J. Pearson. 1984. Diagnosis and correction of nutritional problems, including the crinkle leaf disorder. In: Calif. Pistachio Ind. Ann. Rpt. 1984. pp. 49-50.
10. Uriu, K., and J. Pearson. 1986. Zinc deficiency in pistachio-diagnosis and correction. In: Calif. Pistachio Ind. Ann. Rpt. 1986. pp. 71-72.
11. Uriu, K., Teranishi, R., Beede, R., and J. Pearson. 1989. Copper deficiency in pistachio. In: Calif. Pistachio Ind. Ann. Rpt. 1989. pp. 77.
12. Weinbaum, S.A., and T.T. Muraoka. 1988. Nitrogen usage and fertilizer recovery by mature pistachio trees. . In: Calif. Pistachio Ind. Ann. Rpt. 1988. pp. 84-86.
13. Weinbaum, S.A., Picchioni, G. A., Brown, P.A., Muraoka, T.T., and L. Ferguson. 1991. Nutrient demand, storage and uptake capacity of alternate bearing pistachio. In: Calif. Pistachio Ind. Ann. Rpt. 1991. pp. 148-157.
14. Weinbaum, S., Brown, P., and R. Rosecrance. 1993. Assessment of nitrogen uptake capacity during the alternate bearing cycle. In: Calif. Pistachio Ind. Ann. Rpt. 1993. pp. 47-48.
15. Weinbaum, S., Brown, P., and R. Rosecrance. 1995. Assessment of nitrogen and potassium uptake capacity during the alternate bearing cycle. In: Calif. Pistachio Ind. Ann. Rpt. 1995. pp. 56-60.

Nitrogen Transformations, ¹⁵N Assimilation and Recovery for California Almonds

Daniel L. Schellenberg ^{a,*}, Saiful Muhammad ^b, Maria M. Alsina ^b, Tao Cheng ^c,
Michael Whiting ^c, Blake L. Sanden ^d, Patrick H. Brown ^b and David R. Smart ^a

^a *Department of Viticulture and Enology*

^b *Department of Plant Sciences*

^c *Department of Land Air and Water Resources*

^d *Kern County Cooperative Extension*

University of California Davis

*Corresponding author:

dschel@ucdavis.edu

Phone: +1-530-754-7144

Fax: +1-530-752-0382

Introduction

Nitrogen (N) fertilization strategies offer a manageable approach to regulating the complex nature of the N cycle in agricultural systems (Smart et al. 2011) (See Fig. 1). Effective strategies include split timing of applications, targeted placement through micro-irrigation systems, adequate rates and selection of appropriate N sources. The N budget approach offers a valuable tool for efficient management of fertilizer resources however, does not capture soil N transformations as well as trace losses of the greenhouse gas nitrous oxide (N₂O). In perennial agricultural systems such as deciduous orchards, N inputs originate from organic sources including soil organic matter and leaf litter fall as well as inorganic fertilizers. Organic N transforms first into ammonium (NH₄⁺) before potential nitrification into nitrate (NO₃⁻) while inorganic fertilizers may take on Urea [(NH₂)₂COH], NH₄⁺ or NO₃⁻ forms. In order to conserve soil, water and fertilizer resources, strategies can be taken to slow nitrification and to foster dissimilatory NO₃⁻ reduction to NH₄⁺ (DNRA). As a result, N losses of soil NO₃⁻ via leaching and denitrification may be minimized and conditions will arise for maximum recovery by the tree and subsequent crops. In the following, we describe our approach and summarize emerging trends from an isotope study using ¹⁵N in almond.

Approach

Almond trees were identified for targeted ¹⁵N enrichment during the summer 2010 on a Milham sandy loam near Lost Hills, CA. Treatments of ¹⁵NH₄NO₃ and NH₄¹⁵NO₃ (10% ¹⁵N a.e.) were pulse-injected through the static sprinkler micro-irrigation system. Soil and gas sampling was conducted at 0, 1 and 2 days after fertilization (DAF) after ¹⁵N injection for estimation of gross nitrogen transformations (Hart et al. 1994) DNRA (Silver et al. 2005), soil and root assimilation and ¹⁵N₂O emissions (Alsina et al. *In press*). In 2010, 2011 and 2012 almond kernel, hull and shell were collected and scaled along with tree yield to estimate ¹⁵N crop recovery. In 2012, wood cores were taken from tree roots, branches, trunk and scaffold to estimate ¹⁵N in the standing tree biomass. Leaves were also collected for ¹⁵N analysis and a remote sensing approach was used to determine tree leaf biomass. All samples for isotopic analysis were conducted by the UC Davis Stable Isotope Facility.

Nitrogen transformations

At 1 DAF, gross nitrification exceeded DNRA while gross mineralization was lower and NH₄⁺ consumption and NO₃⁻ consumption were greater than at 2 DAF. At 2 DAF, both DNRA and gross mineralization increased while gross nitrification, NH₄⁺ and NO₃⁻ consumption

decreased compared to 1 DAF. These results support the notion that fertilization stimulates oxidation and consumption of N within 1 DAF and that the system shifts progressively toward greater soil N supply from mineralization and soil N retention by DNRA within 48 hours.

¹⁵N assimilation and N₂O emissions

At 1 DAF, the soil assimilated more N than at 2 DAF and up to an order of magnitude greater than tree roots. The predominant sink for tree roots was NO₃⁻ however; evidence suggests that tree roots directly take up NH₄⁺ as well. Peak ¹⁵N₂O emissions were observed at 1 DAF and were substantially greater from ¹⁵NH₄NO₃ compared to NH₄¹⁵NO₃. These results are consistent with results at the field scale that showed significantly greater N₂O emissions from a predominantly NH₄⁺-based fertilizer of urea ammonium nitrate (UAN) compared to a majority NO₃⁻-based fertilizer in calcium ammonium nitrate (CAN) (Schellenberg et al. 2012).

Crop and tree recovery

Enrichment of ¹⁵N in the almond crop was found with 2010, 2011 and 2012 and continues to be present in the standing tree biomass. We hypothesize that residual ¹⁵N will reside in the soil after 2012 and will continue to be available for uptake and/or potential loss via leaching and/or denitrification. As a result, estimates for a total N balance remain inconclusive. The most important finding is crop and tree recovery of ¹⁵N was substantially greater for ¹⁵NH₄NO₃ compared to NH₄¹⁵NO₃.

Conclusion

Tradeoffs exist between N recovery and greenhouse gas emissions. Both parameters were greater for ¹⁵NH₄NO₃ which, suggests the positively charged NH₄⁺ ion held in the upper horizons of the soil profile are both more available for recovery over time and susceptible to trace losses of the greenhouse gas, N₂O. Lower N₂O emissions from NO₃⁻ and the lower recovery suggest a combination of N losses via leaching or N retention from conversion of inorganic fertilizer to dissolved organic nitrogen (DON) may play an important role. These results support continued voluntary action by almond growers to self-evaluate effective fertilization strategies that encompass timing, placement, rate and source.

References

- Alsina, M. M., A. Borges, and D. R. Smart. *In press*. Spatiotemporal variation of event related N₂O and CH₄ emissions during fertigation in a California almond orchard. *Ecosphere*.
- Hart, S. C., J. M. Stark, E. A. Davidson, and M. K. Firestone. 1994. Nitrogen mineralization, immobilization, and nitrification. *in* R. W. Weaver, C. Angle, and P. Bottomley, editors. *Methods of soil analysis: biochemical and microbiological properties*. Soil Science Society of America, Madison, WI, U.S.A.
- Schellenberg, D. L., M. M. Alsina, S. Muhammad, C. M. Stockert, M. W. Wolff, B. L. Sanden, P. H. Brown, and D. R. Smart. 2012. Yield-scaled global warming potential from N₂O emissions and CH₄ oxidation for almond (*Prunus dulcis*) irrigated with nitrogen fertilizers on arid land. *Agriculture Ecosystems and Environment* **155**:7-15.
- Silver, W. L., A. W. Thompson, A. Reich, J. J. Ewel, and M. K. Firestone. 2005. Nitrogen cycling in tropical plantation forests: potential controls on nitrogen retention. *Ecological Applications* **15**:1604-1614.
- Smart, D. R., M. M. Alsina, M. W. Wolff, M. G. Matiasek, D. L. Schellenberg, J. P. Edstrom, P. H. Brown, and K. M. Scow. 2011. Nitrous oxide emissions and water management in California perennial crops. Pages 227-255 *in* L. Guo, A. S. Gunasekara, and L. L. McConnell, editors. *Understanding Greenhouse Gas Emissions from Agricultural Management*. American Chemical Society, Washington, DC.

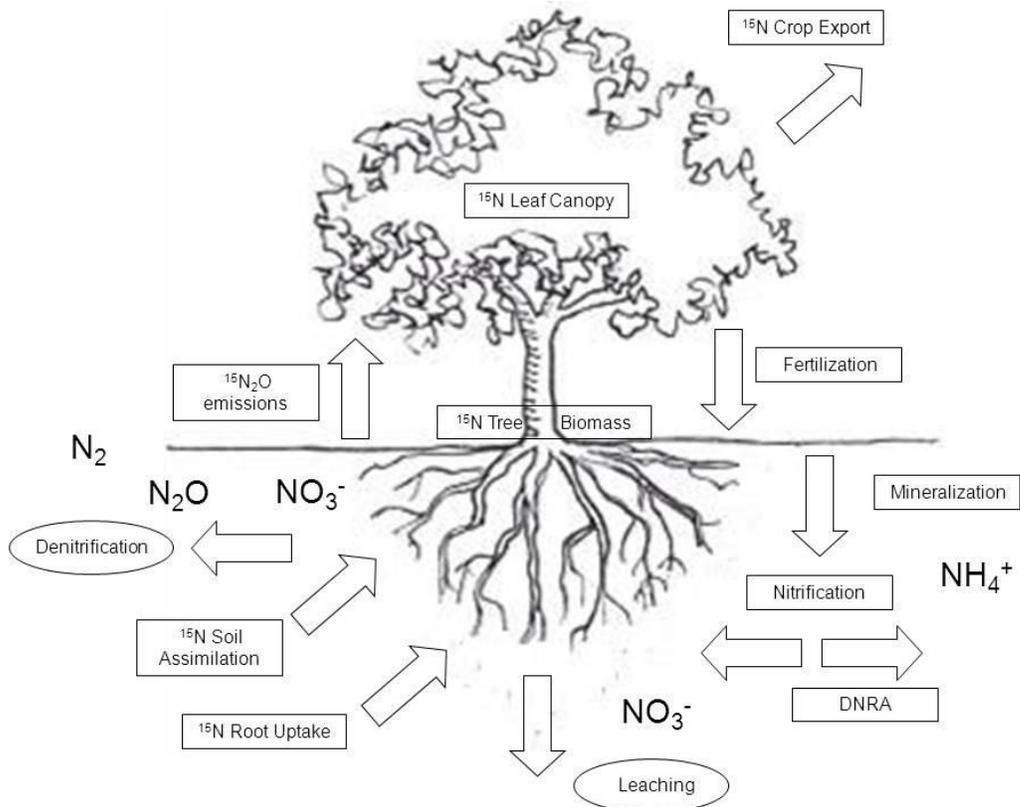


Figure 1. Nitrogen (N) transformations include mineralization of soil organic N, nitrification of ammonium (NH_4^+) into nitrate (NO_3^-) and dissimilatory NO_3^- reduction to NH_4^+ (DNRA). Assimilation includes abiotic and biotic soil sinks as well as tree roots. The major pathways for N loss are leaching and denitrification where trace amounts of N may be lost as the greenhouse gas nitrous oxide (N_2O). Aboveground N is found in the standing tree biomass and exported in the kernel, hull and shells of the almond crop. Leaves return the soil and along with water and fertilizer constituent primary N inputs.

N Management: Almonds where we been, where we are going?

Gabriele Ludwig
Almond Board of California
1150 Ninth Street, Suite 1500
Modesto, CA 95354 USA
Phone: (209) 549-8262
Fax: (209) 549-8267
E-mail: gludwig@almondboard.com

Please contact the presenter for more information on this topic.

NOTES & QUESTIONS

Remediation of tile drain water using denitrification bioreactors

T.K. Hartz, Extension Specialist, Department of Plant Sciences, University of California, 1 Shields Ave. Davis, CA 95616, 530 752-1738, tkhartz@ucdavis.edu

Mike Cahn, UCCE Irrigation Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901, 831 759-7377, mdcahn@ucdavis.edu

Richard Smith, UCCE Vegetable Crops Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Abbott Street, Salinas, CA 93901, 831 759-7357, rifsmith@ucdavis.edu

Laura Tourte, UCCE Farm Management Farm Advisor, Monterey, San Benito and Santa Cruz Counties, 1432 Freedom Boulevard, Watsonville, CA 95076, 831 763-8005, ljtourte@ucdavis.edu

Introduction

Vegetable growers on the Central Coast face an unprecedented challenge from environmental water quality regulation. The Central Coast Region Water Quality Control Board has added new monitoring and reporting requirements to the recent renewal of the Conditional Waiver for Irrigated Lands. The waiver renewal focuses on nitrate ($\text{NO}_3\text{-N}$) pollution abatement; extensive monitoring in recent years has shown that the $\text{NO}_3\text{-N}$ concentration in surface runoff and tile drain effluent from fields in this region commonly exceeds the Federal drinking water standard of 10 PPM. Surface water $\text{PO}_4\text{-P}$ is also commonly above environmental targets. While Central Valley growers face less pressure regarding nutrients in surface water, there are ‘hot spots’ that are drawing regulatory scrutiny.

While better fertilizer management practices can reduce the nutrient load in agricultural wastewater, it is clear that some remediation will also be needed to consistently meet desired environmental levels. Of the techniques that have been considered for the remediation of agricultural wastewater, biological denitrification (BD) appears to be the most promising. BD is a passive process in which bacteria reduce NO_3^- to gaseous N compounds (mostly N_2). The requirements for BD to occur are an anaerobic environment, the presence of bacteria capable of this transformation, and labile carbon to power bacterial growth and act as a terminal electron acceptor in the reduction of $\text{NO}_3\text{-N}$. This process occurs naturally in wetlands, but limited availability of labile carbon limits the rate at which denitrification occurs, making the use of wetlands to remediate agricultural wastewater problematic.

An alternative approach to harnessing BD is the use of a denitrification bioreactor. A bioreactor consists of a chamber filled with an organic waste material through which agricultural wastewater flows. The organic waste material (most often wood chips) supplies labile carbon while providing a physical matrix on which the denitrifying bacteria can grow. Bioreactors have been evaluated in various agricultural areas around the world, with reasonably consistent success. We are currently testing this technique on commercial farms in the Salinas Valley.

Methods

Two pilot-scale bioreactors were constructed in 2011 on tile-drained commercial vegetable farms in the Salinas Valley. Pits of approximately 930 ft^3 (site 1) and 450 ft^3 (site 2)

were dug, lined with polyethylene sheeting, and filled with chipped wood waste obtained from the Monterey Regional Waste Management District. This material, made by grinding untreated scrap construction wood, is available in sufficient quantity (approximately 7,500 tons per year) to represent a potential source of carbon-rich media for commercial-scale bioreactors in this region. Pumps were installed in the collection sumps of the farms' tile drain systems. Tile drain water is continuously pumped into the bioreactors at a rate to provide approximately 2 days of residence time in the reactors before the water is released into the surface ditches draining the farm. Since May (site 1) or June (site 2), 2011, inlet and outlet water from the reactors has been sampled 2-3 times per week during the crop production season, and once per week during the winter. The water collected has been analyzed for nitrate-nitrogen ($\text{NO}_3\text{-N}$) and dissolved organic carbon (DOC).

In May, 2012, a pilot-scale bioreactor was constructed on a commercial farm in the Salinas Valley (site 3) to evaluate the remediation of surface runoff from vegetable fields. This reactor is approximately 430 ft^3 in volume, and contains the same chipped wood waste used for the 2011 bioreactors, although of a finer grind (most chips < 1", whereas the 2011 bioreactors were filled with 1-2" chips). Water is continuously pumped into the bioreactor from a tailwater collection pond. Because this water contains a large sediment load that would foul the bioreactor, the water is pre-treated with polyacrylamide (PAM) to flocculate soil particles before it is pumped into the bioreactor. This reactor has been operational since June 1, 2012.

Results

A high level of DOC was present initially in the outflow from all bioreactors, but declined to approximately 20 PPM after several weeks of operation, only marginally higher than the incoming water. High DOC may stimulate the biological oxygen demand of the receiving waters. Additionally, the color of the reactor effluent in those initial weeks of operation was quite dark, suggesting that complex organic compounds were being leached from the wood chips. To minimize any adverse environmental effects arising from the operation of a bioreactor, water released during the initial weeks of operation might best be reapplied on-farm, perhaps as pre-irrigation water. Tile drain effluent presents a potential problem in this regard, as it can be relatively high in salinity (the typical electrical conductivity of bioreactor effluent has been 3-4 dS/m); blending with higher quality water may be required. After a few weeks of operation, bioreactor effluent does not appear to pose any significant environmental risk.

At all sites, denitrification began within days of the initial filling of the bioreactors; denitrifying bacteria are ubiquitous, and 'seeding' of inoculum was not necessary. High initial denitrification rates slowed as the reactors matured, undoubtedly related to reduced carbon availability. Once the reactors at sites 1 and 2 reached a 'steady state' condition, denitrification rates averaged approximately 8 PPM $\text{NO}_3\text{-N}$ per day of residence time during the rest of the 2011 irrigation season (July through October), and approximately 5 PPM during the winter (Figure 1). Denitrification rates from May through July, 2012, have been similar to those achieved during the first summer of operation, suggesting long-term stability of performance. Equipment problems at both sites periodically resulted in residence time longer than 2 days; the mean daily denitrification rates cited have been adjusted for these events.

The initial months of operation at site 3 have been encouraging (Fig. 2). Surface runoff $\text{NO}_3\text{-N}$ concentration has ranged between 20-50 PPM. Average $\text{NO}_3\text{-N}$ reduction was approximately 13 PPM per day of residence time from June through October; this was sufficient to reduce $\text{NO}_3\text{-N}$ below the 10 PPM regulatory standard on a number of sampling dates. The

denitrification rate of this bioreactor may decline as it ‘matures’, but it is possible that the smaller wood chips used at site 3 will continue to support higher denitrification rates than at sites 1 and 2 due to higher carbon availability and/or greater surface area on which the denitrifying bacteria can grow. Furthermore, the temperature of surface runoff has averaged about 8 °F higher than the tile drain effluent, encouraging greater denitrification.

The lower initial NO₃-N concentration of surface runoff compared to tile drain effluent makes the use of this technology more practical for the treatment of surface runoff, provided that efficient sediment removal can be achieved. The simple system of PAM treatment that we are using is removing > 90% of sediment content. Maintaining a bioreactor over many years of operation would require an even more efficient system of sediment removal; prior research has suggested that this should be technically feasible.

Despite the encouraging results to date, significant questions remain regarding the potential of this technology to substantively reduce the water quality impacts of irrigated agriculture. The costs, and the engineering constraints, of scaling up bioreactors to handle tens of thousands of gallons of tile drain effluent or surface runoff per day have yet to be evaluated. The useful life of a bioreactor is not clear. Some small-scale bioreactors have been in service for more than a decade in the Midwest. Our initial experience suggests that the degradation of the wood chips is slow, probably about 10% per year by weight. However, changes in bioreactor hydraulic characteristics, or fouling from sediment content (in the case of surface runoff), may require more frequent renovation. What seems clear is that, to be maximally effective, denitrification bioreactors would be only one element of an integrated irrigation and nutrient management system that minimizes both the volume and NO₃-N load of agricultural discharge.

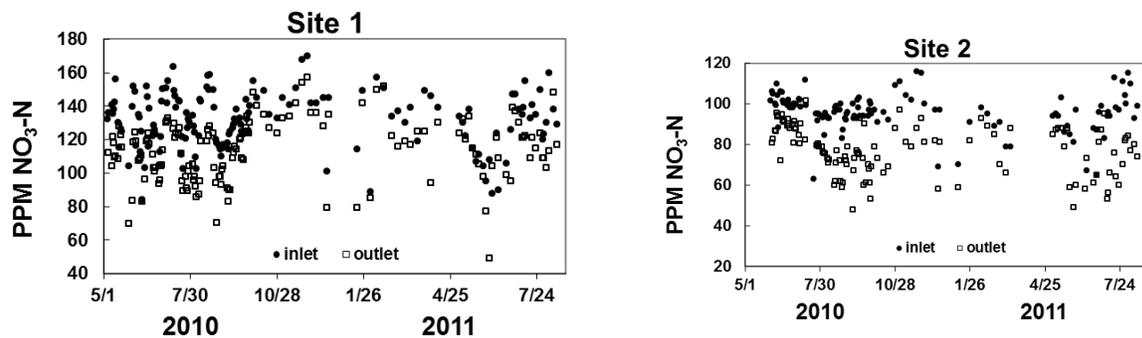


Figure 1. Reduction of water NO₃-N concentration in the denitrification bioreactors treating tile drain effluent.

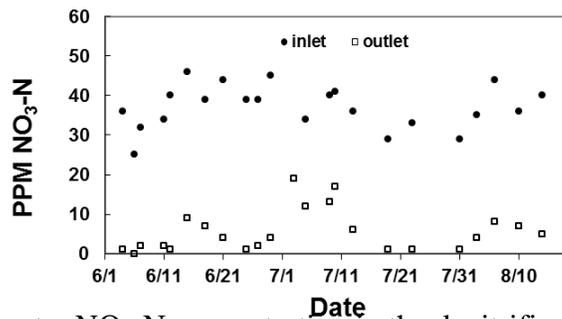


Figure 2. Reduction of water NO₃-N concentration in the denitrification bioreactor treating surface runoff (site 3).

Improved Methods for Nutrient Tissue Testing in Alfalfa

Daniel Putnam, Extension Specialist, University of California, Davis,
Department of Plant Sciences, One Shields Ave., Davis, CA 95616
Phone (530) 752-8982, dhputnam@ucdavis.edu

Steve Orloff, UC Farm Advisor, Siskiyou County
1655 Main Street, Yreka, CA 96097
Phone (530) 842-2711, sborloff@ucdavis.edu

Chris DeBen, Staff Research Associate, University of California, Davis,
Department of Plant Sciences, One Shields Ave., Davis, CA 95616
Phone (530) 754-7521, cmdeben@ucdavis.edu

Introduction

Alfalfa is the largest acreage crop in California with over 950,000 acres in 2012. Because of its acreage and nutrient requirements, alfalfa represents an important component of California's fertilizer and agricultural footprint. The most limiting nutrients for alfalfa production in California are phosphorus followed by potassium, sulfur, and occasionally micronutrients in some locations. Despite the importance of fertility management, many growers do not know whether their fields are deficient, in excess, or adequate. Fertilizer practices are usually based primarily on past practices with little knowledge of the current nutrient status of fields.

Soil tests are effective to detect nutrient deficiencies such as P and K, and are especially useful before planting. However, plant tissue tests are believed to be far more accurate, especially for sulfur and micronutrient analysis. The plant is a better indicator of the nutritional status of a field due to soil sampling and laboratory nutrient extraction limitations. Alfalfa roots penetrate 5 feet or more into the soil and nutrient concentrations vary with soil depth yet we typically only sample the top 6 to 8 inches. Additionally, lab extraction techniques may differ from the nutrients actually available to a plant in the field. Plant analysis is an indicator of actual nutrient uptake and therefore a better measure of nutrient availability. Unfortunately, most alfalfa growers currently do not utilize tissue testing. There is a need to encourage better management of nutrients in general (excess, deficiencies), but in particular to more widely adapt soil and tissue testing protocols.

Obstacles to the Adaption of Tissue Testing Practices

The established alfalfa tissue testing protocol in California involves collecting stems at the time of cutting (ideally 10 percent bloom) and fractionating the plant into 3 parts and analyzing each part for a distinct nutrient(s). For alfalfa producers and consultants, this process can be time consuming, tedious and confusing. In addition, there is no way to sample after the crop has already been harvested. This sampling procedure is unique to California and other states have different protocols with no universal nationwide sampling method. Typically, either whole plant or the top 6" (15 cm) of the plant is used, and the samples taken at early or 10% bloom (Kelling, 2000, Koenig et al., 1999, Koenig et al., 2009, Flynn et al., 1999).

Many alfalfa crops in California are routinely tested for forage quality (e.g. fiber, protein and calculated digestibility values) to determine their nutritional value for feeding purposes by coring the hay bales after harvest. If these same cored samples used for forage quality analysis could also be used for nutrient management purposes, it would greatly simplify the process, promote the practice of tissue sampling to guide fertilizer applications and encourage more careful nutrient management. Also, because core sampling of hay stacks represents a wide range of plant material (greater than grab samples of the standing crop), it may be more successful at representing the overall nutrient status of a field. Cored bale samples also provide a mechanism for assessing the nutritional status of the field post-harvest.

Comparison Of Sampling Techniques

A multiyear project was initiated to compare soil samples, cored-hay samples, whole top samples, and fractionated stem samples using the UC technique. The results indicated that cored-bale samples provided results very similar to the fractionated stem samples. The mid-stem samples were analyzed for phosphate phosphorus (PO₄-P) and potassium and the mid-stem leaves were analyzed for sulfate sulfur (SO₄-S). Cored bale samples and whole-top plant samples were analyzed for PO₄-P, total phosphorus, total sulfur, SO₄-S, and potassium. Figure 1 shows the relationship between mid-stem PO₄-P concentration and the total phosphorus content of the cored bale samples. The two sampling methods were closely related. Likewise there was a strong relationship between the fractionated stem samples and cored bale samples for potassium and sulfur concentration. These results suggest that the cored bale sampling technique could be used successfully in lieu of fractionated stem samples.

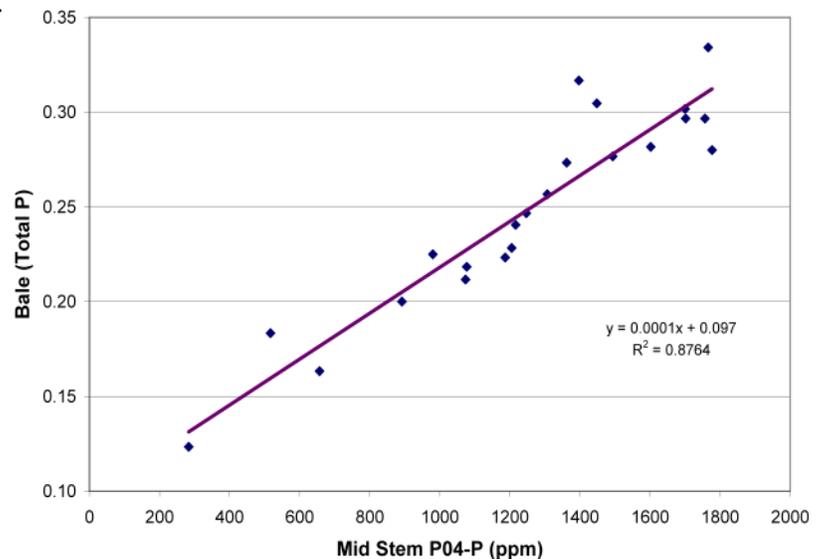


Figure 1. Relationship between mid-stem PO₄-P concentration and the total phosphorus concentration of cored bale samples.

Effects of Plant Maturity

Current plant tissue interpretation guidelines for California (Meyer et al., 2007) and other states throughout the US (Koenig et al., 2009) are based on alfalfa at the one-tenth bloom growth stage. However, to produce highly digestible alfalfa for the dairy industry, growers will frequently harvest alfalfa in the bud stage and many fields never reach one-tenth bloom before harvest. Thus, studies were conducted to assess the effect of plant maturity on nutrient concentrations for three different sampling methods 1) fractionated plant sample (standard UC protocol), 2) top 15 cm of the alfalfa plant (method used in many other alfalfa-producing states) and 3) whole-plant samples (used in some states and comparable to cored bale samples).

Samples were collected three times over the season (early, mid, and late-season) from commercial alfalfa fields in three different alfalfa production regions (Intermountain area, Sacramento Valley and the High Desert). Samples were collected at the early-bud, late-bud, and 10 percent bloom growth stages at each of the three cuttings to determine the effect of plant maturity on nutrient concentration. The mid-stem portion of alfalfa plants is the plant part used to assess P and K status using the UC fractionated plant sampling technique. Although the R^2 values for the relationship between mid-stem vs. whole plant P or K status were not always extremely high, they were always positive and statistically significant. Both methods appeared to detect nutrient status of the plants at different fertility levels. This confirms previous findings that in all likelihood, whole plant samples (similar to bale samples) can be used to determine nutrient concentration levels. This has considerable practical importance. Since whole plants are routinely sampled for forage quality, this would enable producers to use the same sample for both purposes greatly encouraging the adoption of tissue sampling to ascertain fertilizer needs.

Concentration Changes with Maturity

One of the key impediments to the standardization of sampling methods in alfalfa is the influence of plant maturity on nutrient concentrations. This is important for either standing crop sampling, bale sampling or with plant fractions. The change in nutrient concentration with crop maturity stage has not been adequately accounted for in previous guidelines developed for alfalfa tissue testing. Most guidelines simply state that they are based on alfalfa at the 10 percent bloom stage without indicating how to evaluate less mature alfalfa samples.

In agreement with previous research (Schmierer *et al*, 2005), we found that nutrient concentrations were significantly affected by alfalfa growth stage. For P analysis, all three methods (whole plant, top 15 cm and stem) provide similar (parallel) results, but with different average concentrations for each method (Figure 2). There was a consistent gradual decline in P concentration with advancing maturity. Potassium concentration also decreased with advancing maturity but the decline was more precipitous (Figure 3). In addition,

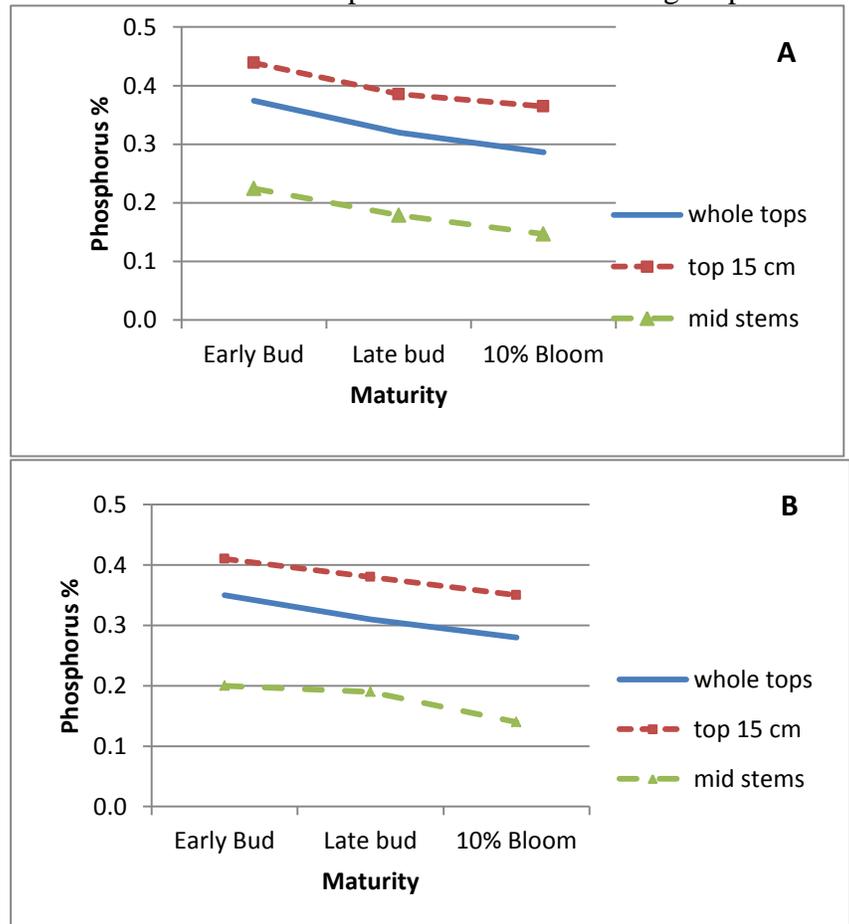


Figure 2. Influence of plant maturity on phosphorus concentrations in alfalfa, average of 10 farms, and all cuttings, (A) 2010 and (B) 2011. Note: Whole tops and top 15 cm are expressed as total P, whereas mid-stem phosphorus is expressed as PO₄-P.

the decline in potassium concentration with advancing alfalfa maturity was not as linear as it appeared for phosphorus (Figure 3). In general, the potassium concentration declined more dramatically when alfalfa matured from the late bud stage to the 10 percent bloom stage than it did from the early to late bud stage. Sulfur concentrations were not as greatly affected by stage of development, but there was still some influence (data not shown).

These results clearly demonstrate that alfalfa maturity must be considered when interpreting alfalfa plant tissue levels for both phosphorus and potassium. Previous guidelines (Meyer *et al.*, 1997) suggested that nutrient concentrations were only 10 percent higher in bud stage than in 10 percent bloom alfalfa; however, our research clearly demonstrates that the difference is far greater, approximately a 30 percent difference between 10 percent bloom and early-bud stage alfalfa. This has likely led to considerable interpretation errors in the past when evaluating plant tissue test results from samples taken prior to the 10 percent bloom stage. For example, a sample collected at early bud stage may appear to have adequate phosphorus but if the same plants were sampled at one-tenth bloom they may be deficient. Critical plant tissue levels are currently being developed to allow for accurate interpretation of bud-stage alfalfa.

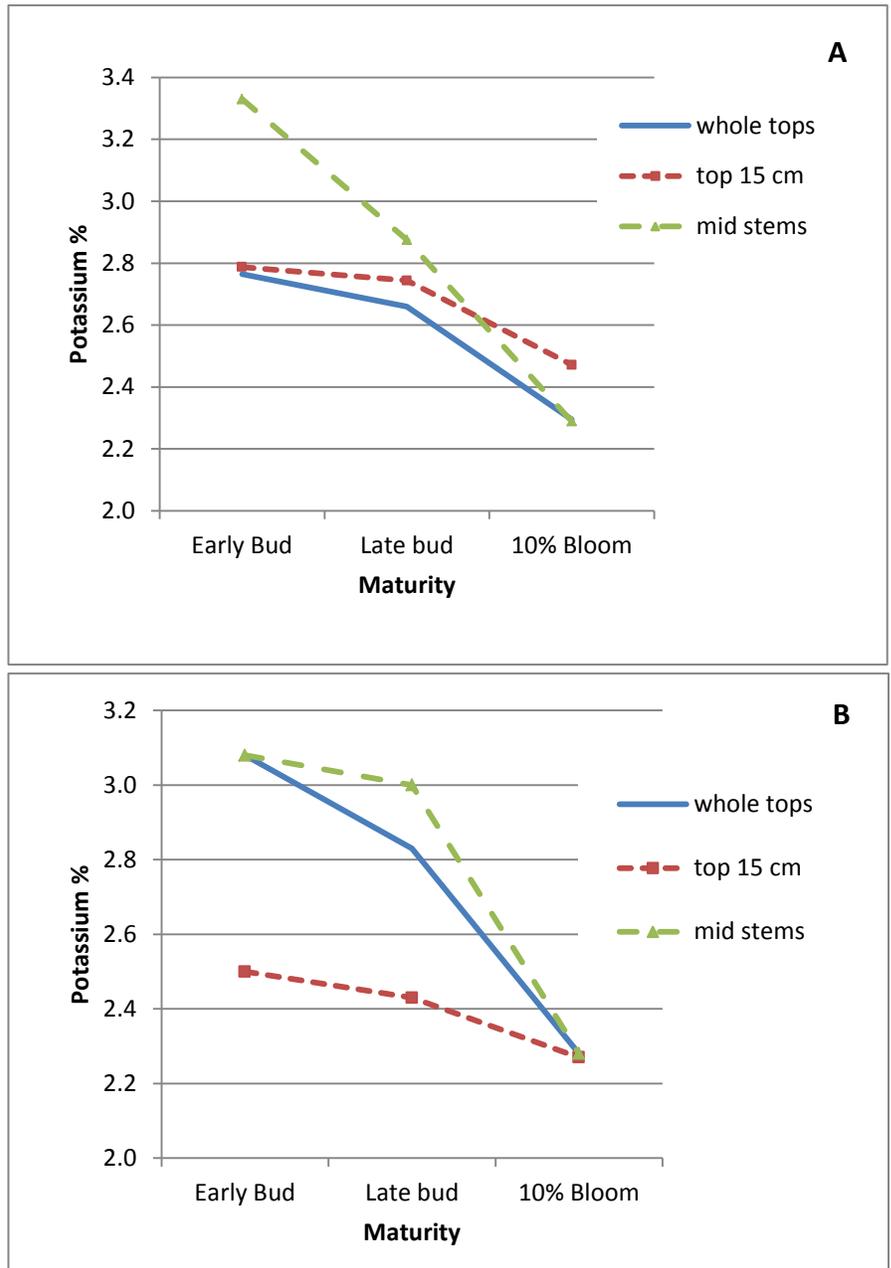


Figure 3. Influence of plant maturity on potassium concentrations in alfalfa, average of 10 farms, and all cuttings, (A) 2010 and (B) 2011.

Utilizing NIRS for Detection of Deficiencies in Alfalfa

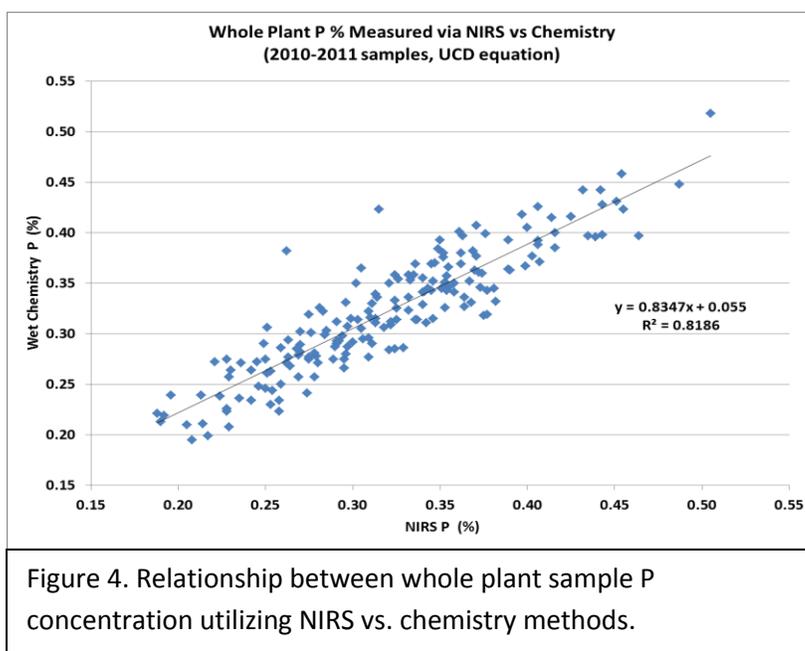
A large percentage of alfalfa hay in California is analyzed with either wet chemistry or near-infrared spectroscopy (NIRS) methods to assess its nutritional value. This technique is used primarily for the evaluation of typical forage quality parameters (Dry Matter, Acid Detergent Fiber, Neutral Detergent Fiber, Crude Protein), but some commercial labs also report values for minerals. NIRS technology, which uses light reflectance and calibration equations to estimate hay quality parameters, has become widely accepted because it is faster, highly repeatable and usually less expensive. Although wet chemistry techniques are ordinarily preferred for mineral analysis, some labs have proposed utilizing NIRS (an indirect method) for estimating nutrient concentrations. This may become especially useful with the monitoring of nutrients in crops for the purposes of nutrient management plans. The use of NIRS methodology could greatly simplify alfalfa plant tissue testing if reliable calibration equations exist, or could be developed, for routine prediction of the nutrient status of fields. Note: nitrogen is a very reliable parameter to measure utilizing NIRS – Crude protein values are calculated from %N in plant tissue utilizing robust NIRS equations. However, P, K and S analyses have not been as widely accepted.

NIRS scans were performed on samples from 2010 and 2011, in both the UC Davis lab and a cooperating commercial lab (JL Analytical Services). We used a large set of samples to compare NIRS methodology for prediction of minerals with wet chemistry (standard) procedures. Correlations with NIRS-predicted values compared with wet chemistry values for a range of samples from our studies found relatively high R^2 values. Correlations were 81% (Putnam lab equation, Figure 4) for phosphorus. Additionally, R^2 values of 76% to 78% for K were observed using a commercial lab equation and the NIRS Consortium equation.

Sulfur correlations (NIRS vs. chemistry) were lower so it is questionable at this point whether NIRS can be used to estimate the sulfur status of an alfalfa field. We tentatively conclude that NIRS can be used for early routine detections of phosphorus and potassium nutrient deficiencies (and perhaps for uptake analysis), but caution should be exercised on this issue, since the mechanism for response of NIRS to different nutrient concentrations is not fully understood.

Conclusions

Analysis of whole plant or cored bale samples for detection of P and K deficiencies appears to be a practical method to monitor deficiencies of these nutrients in commercial alfalfa fields. Plant stage of development has a large influence on nutrient concentrations, especially for phosphorus and potassium. Therefore, different threshold values will be required to account for plant growth stage at the time of sampling. It is likely that NIRS methods can be useful for early



detection of nutrient deficiencies, especially phosphorus and potassium. Since many growers routinely analyze their alfalfa hay for nutritional quality using NIRS, this may be a simple method to evaluate the need for supplemental fertilizer. However, an initial NIRS analysis should likely be followed up with more vigorous field testing to confirm the nutritional status of the field. It was apparent that alfalfa tissue testing protocols using whole tops or cored bale samples are simple to use and sufficiently accurate so that nutrient analysis can become a routine component of forage quality testing. Additional work is underway to establish critical plant tissue values for whole tops or cored bale samples at different sampling maturities.

Literature Cited

- Kelling, K.A. 2000. Alfalfa Fertilization. Publication A2448 University of Wisconsin Cooperative Extension . <http://learningstore.uwex.edu/assets/pdfs/A2448.pdf>
- Koenig, R. T., D. Horneck, T. Platt, P. Petersen, R. Stevens, S. Fransen, and B. Brown. 2009. Nutrient Management Guide for Dryland and Irrigated Alfalfa in the Inland Northwest. A Pacific Northwest Extension Publication. PNW0611. Washington State University. <http://cru.cahe.wsu.edu/ceppublications/pnw0611/pnw0611.pdf>
- Koenig, R., C. Hurst, J. Barnhill, B. Kitchen, M. Winger, M. Johnson. 1999. Fertilizer Management for Alfalfa. Utah State University Publication AG-FG-01. <http://extension.usu.edu/files/publications/publication/AG-FG-01.pdf>
- Flynn, R., S. Ball, R. Baker. 1999. Sampling for Plant Tissue Analysis. Guide A-123. New Mexico State University. http://aces.nmsu.edu/pubs/_a/a-123.html
- Meyer, R.D., D.B. Marcum and S.B. Orloff. 1997. "Fertilization." In S.B. Orloff and H.L. Carlson (eds.), Intermountain Alfalfa Management. 41–49 Oakland: University of California Division of Agriculture and Natural Resources, Publication 3366.
- Meyer, R.D, D.B Marcum, S.B. Orloff and J.L. Schmierer. 2007. "Alfalfa Fertilization Strategies." In Charles G. Summers and Daniel H. Putnam (eds.), Irrigated Alfalfa Management for Mediterranean and Desert Zones. Oakland: University of California Division of Agriculture and Natural Resources, Publication http://alfalfa.ucdavis.edu/IrrigatedAlfalfa/pdfs/UCAlfalfa8292Fertilization_free.pdf
- Orloff, S., D. Putnam, and R. Wilson. Maximizing fertilizer efficiency through tissue testing and improved application methods, 2008 California Alfalfa & Forage Symposium and Western Alfalfa Seed Conference, San Diego, CA, 2-4 December 2008 <http://alfalfa.ucdavis.edu/+symposium/proceedings/2008/08-275.pdf>
- Schmierer, Jerry L., R. Meyer, and D. Putnam. 2005. Testing alfalfa for phosphorus and potassium nutrient deficiencies. Proceedings, 35th California Alfalfa and Forage Symposium, 12–14 Dec. 2005. Visalia, CA. UC Cooperative Extension. pp. 201–208. http://alfalfa.ucdavis.edu/+symposium/proceedings/asdf/alf_symp/2005/05-201.pdf



American Society of Agronomy

California Chapter

Session IV
Crop Production
&
Mechanization

Session Chairs:
Bob Hutmacher
Warren Hutchings

Mechanical Harvesting of Table Olives: California and Spain

Louise Ferguson, Dept. Plant Sciences, Univ. California Davis, Davis, CA 95616, Phone: (530)

752-0507, lferguson@ucdavis.edu

J.A. Miles, Dept. Biological and Agric. Engr., Univ. California Davis, Davis, CA 95616

U.A. Rosa, Agric. Div., Trimble Navigation Ltd, 935 Stewart Dr., Sunnyvale, CA 94085

S. Castro-Garcia, Dept. of Rural Engineering, E.T.S.I. Agrónomos y Montes, Univ. Cordoba, Campus de Rabanales, Ctra. Nacional IV Km 396, Córdoba, Spain

E. Fichtner, Univ. California Cooperative Extension, Tulare County, Visalia, CA 93274

W.H. Krueger, Univ. California Cooperative Extension, Glenn County, Orland, CA 95963

J.X. Guinard, S.M. Lee, Dept. Food Science & Tech., Univ. California, Davis, CA 95616

K. Glozer, C. Crisosto, Dept. Plant Sciences, Univ. California Davis, Davis, CA 95616

J.K. Burns, Lake Alfred Citrus Res. & Extn. Ctr., Univ. Florida, Lake Alfred, FL 33850

Gregorio L. Blanco-Roldán, Jesús A. Gil-Ribes, Dept. Rural Engr., E.T.S.I. Agrónomos y Montes, Univ. Cordoba, Campus de Rabanales, Ctra. Nacional IV Km 396, Córdoba, Spain

California and Spain both produce table olives. California's primary cultivar is the *Olea europea* Cv. 'Manzanillo' which is harvested physiologically immature and processed with oxidation to produce the 'California Black Ripe' olive. Spain produces green 'Spanish style' olives from the *Olea europea* Cvs. 'Manzanilla', 'Gordal Sevillana' and 'Hojiblanca'. For both countries hand harvest is the single largest production cost, averaging an unsustainable 50-75% of gross return. Developing mechanical harvesting is necessary for both countries. Both research programs have focused simultaneously on three interacting factors; harvesting technology, tree training and pruning, and identifying an abscission chemical. The last factor, an abscission compound that reliably decreases fruit removal force without unsustainable leaf loss has never been identified. Therefore, the major research efforts have focused on mechanical harvesting technology and adapting the tree for mechanical harvesting.

Both countries have identified two harvesting technologies, trunk shaking and canopy contact that successfully remove olives although efficiencies remain below the desired 80%. In California both harvest technologies have been demonstrated to successfully produce marketable processed 'California black ripe' 'Manzanillo' olives that neither a trained sensory panel or a consumer panel can distinguish from hand harvested olives if the fruit is not harvested overripe. Spain has yet to develop a harvesting technology that produces marketable 'Spanish style' processed green olives though the 'Hojiblanca' cultivar has been demonstrated to bruise less than the 'Sevillana' or 'Manzanilla' cultivars. Both Spain and California have identified tree training and pruning practices that increase harvester efficiency for both harvesting technologies. California results thus far demonstrate that training or pruning orchards to a medium density hedgerow will increase the final harvester efficiency of canopy contact harvesters. Trunk shakers are more efficient if the trees are trained and pruned to have short, stiff upright branches. Research in both countries strongly demonstrates that the orchards will need to be adapted to the harvesting technology. This gives the table olive industry an opportunity to develop higher density orchards designed to efficiently intercept light for optimal production efficiency.

Finally, research in both countries also demonstrates that the harvesters finally developed need to be smaller, lighter and cheaper. The current research on harvesting technology will produce a short term solution. Research on the mid term solution of developing higher density mechanically pruned hedgerow orchards is now beginning. And the long term final goal of genetically modifying trees to facilitate mechanical harvesting is yet to be started.

Keywords: Mechanical harvesting, Mechanical pruning, Hedgerow, *Olea europea* Cv. 'Manzanillo/a', 'Hojiblanca', 'Sevillana' Fruit removal force, Final harvest efficiency

Mechanical Canopy and Crop Load Management of Wine Grapes

S. Kaan Kurtural, Bronco Wine Company Viticulture Research Chair,
Department of Viticulture and Enology, CA State Univ. Fresno
Phone: 559-278-2414; kkurtural@csufresno.edu

Introduction

More than 50% of the 3.6 million tons of wine grapes grown in California each year come from the San Joaquin Valley (SJV) and 60% of the Pinot gris acres are planted in the region. In the SJV, Pinot gris garners a price of \$471.52 per ton (California Dept. Food and Agriculture 2012) with an average yield of 7.47 tons/acre, while total operating costs are \$5007/acre of which 80% are attributed to manual labor operations (Kurtural et al. 2012). The increasing labor operation costs and unavailability of labor are threatening the long-term economic viability of SJV winegrape vineyards.

Much of the wine grapes planted in the SJV are grown on a two or three wire single-curtain, non-shoot positioned trellis (Gladstone and Dokoozlian 2003) commonly referred to as the California sprawl. This trellis type while not capital intensive to install is often utilized improperly, resulting in excessive fruit zone shading under vigorous conditions (Dokoozlian and Kliewer 1995; Terry and Kurtural 2011). With narrow profit margins the majority of growers do not apply principles of canopy management due to cost. To remain profitable they retain too many nodes resulting in out-of-balance vines with less than desirable fruit quality at the farm gate.

Mechanization of canopy and crop load (Ravaz Index) management in vineyards were shown to reduce labor costs by 44% to 80%, maintain yield and quality at the farm gate, and reduce the overhead associated with human resources (Kurtural et al. 2012; Morris 2007; Poni et al. 2004). Literature indicates consistent production in vineyards is achieved by balanced cropping (Howell 2001, Morris 2007, Terry and Kurtural 2011). Balanced cropping aims to achieve equilibrium between vegetative and reproductive growth of the grapevine, and thus ensures consistent vineyard production. Canopy management can achieve balanced cropping in vineyards and provides a set of decision-making steps to improve the canopy microclimate. A combination of mechanical hedging and retaining 7 shoots/ft of row with mechanical shoot thinning with regulated deficit irrigation in the SJV was proven successful maintaining a pruning weight of 0.7 lbs/ft, improving berry skin phenolics while maintaining a yield of 9.9 tons/A with a Ravaz Index of 9.9 lbs/lbs (Terry and Kurtural 2011). However, the economic yield threshold for the SJV at the planting density reported by those authors is 12 tons/A (Peacock et al. 2005). Literature reports a Ravaz Index (ratio of fruit yield to pruning weight) of 5 to 10 lbs yield per lbs of pruning weight to be optimal while maintaining a pruning weight per m of row up to 1.0 kg/m (Kliewer and Dokoozlian 2005) but these values are not specific to the SJV. Therefore,

there is a lack of knowledge how to achieve vine balance in warm climates regarding the economic crop level of Pinot gris.

While there have been numerous reports on adapting mechanical pruning practices, shoot thinning, leaf removal and regulated deficit irrigation on red wine grape cultivars there is limited knowledge on how best to maintain yield and crop load of Pinot gris without adversely affecting fruit composition. The objective of this study was to identify interactive effects of mechanical canopy management on crop load optimization while saving labor operation costs without adversely affecting pruning weight and fruit composition of Pinot gris in a warm climate.

Materials and Methods

Plant materials and site: This study was conducted in 2010 and 2011 at a commercial vineyard planted with ‘Pinot gris/1103P’ (UC Davis clone 03) grapevines at 7 ft × 11 ft (vine × row) spacing in North-South oriented rows. The research site was located in Kern County, California and was planted in 2004 on Premier Sandy-Loam soil. The vines were trained to a single plane, bi-lateral cordon at 54 inches with two foliage support wires at 64 inches (total height of canopy above vineyard floor), and a 10 inch cm t-top, otherwise known as the California sprawl. The vineyard was drip-irrigated with pressure compensating emitters spaced at 38 inches delivering 0.5 gal/h per vine. The experiment was a two (dormant pruning type) × three (shoot thinning) × two (leaf removal) factorial with a randomized complete block design with four replicated blocks. Each experimental unit consisted of 386 vines within each block. There were 48 vines sampled per experimental unit based on a grid pattern of every seventy fourth vine.

Canopy Management Treatments

Dormant pruning: Two dormant pruning treatments were applied: hand pruning and mechanical hedging. Hand pruned vines were spur pruned to retain 40 spurs per vine (control). The mechanical hedging treatment consisted of pruning previous year’s canes to a 4 inch spur height with a 24 inch Sprawl-Pruner (Model 63700; Oxbo International, Kingsburg, CA)

Shoot thinning: Three shoot thinning treatments were applied mechanically at modified E-L stage 17 (Coombe 1995) with a rotary-paddle shoot thinner equipped with an Oxbo 62731 rotary brush. Shoots thinning treatments were applied to a target of 7 count shoots/ft [low] (borne from count positions >5mm distal to the base of the bearing surface), 10 count shoots/ft [medium] or 15 count shoots/ft [high, not thinned], respectively.

Leaf removal: Two leaf removal treatments were applied in the fruiting zone. Leaves were removed 20 days postbloom in an 18 inch zone in the fruiting zone above the cordon, or were not removed. The surface layer of leaves were removed with a vacuum-type mechanical leaf puller (Model 62084; Oxbo International) that consisted of a rotating drum that drew in air and leaves that were sheared from the vine with a sickle bar. Leaves pointing to the interior of the canopy were not removed.

Results

Yield components. In 2010, pruning method and shoot thinning treatments interacted to affect berry weight. A combination of mechanical hedging with high shoot thinning resulted in the smallest berry size. Mechanically hedged vines combined with low or medium shoot thinning resulted in the greatest berry size in 2010. However, in 2011, mechanical hedging decreased berry weight by 18% compared to spur pruning. There was no effect of leaf removal on berry size in either year.

Pruning method and shoot thinning interacted to affect the number of clusters harvested in 2010. The number of clusters per vine was the highest when mechanical hedging was combined with the high shoot density treatment in 2010. In 2011, there was no interaction of factors tested on clusters harvested per vine. In 2011, mechanical hedging increased clusters per vine by 31% compared to spur pruning. High shoot density treatment also increased the number of clusters by 23% compared to low and medium shoot density treatments in 2011. There was no interaction of factors tested on cluster weight or yield of Pinot gris in 2010. Mechanical hedging reduced cluster weight by 14% compared to spur pruning. Mechanical hedging increased yield by 47% compared to spur pruning in 2010. In 2010, high shoot thinning also increased yield by 25% and 15% compared to low and medium shoot thinning, respectively. Pruning method and shoot thinning interacted to affect cluster weight and yield in 2011. Mechanical hedging combined and high shoot thinning resulted in the smallest clusters in 2011. In 2011, hand pruned vines with the high shoot density treatment had the largest yield. A combination of mechanical hedging with low or medium shoot thinning reduced the yield by 8% and 5%, respectively compared to the spur pruned vines with the high shoot thinning treatments.

Fruit composition. The time to reach harvest target of 22 Brix was affected by pruning method and shoot density in 2010. However, the same trend was not evident in 2011. In both years of the study TA of spur pruned vines was higher than mechanically hedged vines. Increasing shoot per m of row decreased TA of Pinot gris at harvest in both years of the study. Leaf removal treatments did not affect Brix, pH in either year of the study. Leaf removal increased TA of Pinot gris in 2011, at harvest.

Yield efficiency. Pruning method and shoot thinning interacted to affect pruning weight and Ravaz Index in 2010. In 2010, hand pruning with the medium shoot thinning treatment had the highest pruning weight, while mechanical hedging with high shoot thinning treatment attained the lowest. In 2011, pruning weight of Pinot gris was affected by pruning method, shoot thinning and leaf removal. Mechanical hedging reduced pruning weight by 27% compared to hand pruning in 2011. Low and medium shoot-thinned vines had 16% and 9% less pruning weight than high shoot-thinned vines. In 2011, leaf removal decreased pruning weight of Pinot gris by 13% compared to vines that received no leaf removal. The Ravaz Index was highest in 2010 for mechanically hedged vines with the high shoot thinning while hand pruned vines with the low shoot thinning resulted in the lowest. The Ravaz Index of mechanically hedged vines

with high shoot thinning were 77% greater than those with hand pruning and the low shoot thinning combination. Shoot thinning was effective in decreasing the Ravaz Index of mechanically hedged vines where 46% and 27% reduction was seen with low and medium shoot thinning compared mechanically hedged vines with high shoot thinning in 2010. In 2011, Ravaz Index of vines with hand pruning with low and medium shoot thinning were 50% and 42% lower than mechanically hedged vines with medium shoot thinning.

In 2010, shoot density and leaf removal interacted to affect the leaf area to fruit ratio. Low shoot thinning and leaf removal treatment combination had lower leaf area to fruit ratio when compared high shoot thinning with no leaf removal. In 2011, pruning method and shoot thinning affected the leaf area to fruit ratio. Leaf area to fruit ratio of mechanically hedged vines was 49% greater compared to hand pruned vines. In 2011, medium shoot-thinned vines had 37% less leaf area to fruit ratio than low or high shoot-thinned vines. There was no effect of leaf removal in leaf area to fruit ratio of Pinot gris in 2011.

Crop load management and labor operation costs and benefit. The economic threshold of 12 tons/A corresponded to a Ravaz Index of 10.3 lbs/lbs and 12.0 lbs/lbs in 2010 ($r^2 = 0.8974$, $p < 0.0001$), and 2011 ($r^2 = 0.4012$, $p < 0.0001$), respectively. The Ravaz Index range identified (10.3 to 12.0 lbs/lbs) resulted in a pruning weight range of 0.62 lbs/ft to 0.77 lbs/ft in 2010 ($r^2 = 0.7480$, $p < 0.0001$) and 2011 ($r^2 = 0.7667$, $p < 0.0001$), respectively. To achieve a Ravaz Index of 10.3 to 12 lbs/lbs, after dormant pruning, 11 shoots/ft need to be retained for Pinot gris ($r^2 = 0.6982$, $p < 0.0001$). This shoot density was only achieved with mechanically hedging previous year's canes to a 4 inch spur height and then mechanically shoot thinning with the medium shoot thinning in this study. This identified treatment cost \$ 536 per acre to apply and provided 79% savings over hand pruning alone while generating positive cash flow. Conversely, hand pruning alone did not meet yield threshold or generate a positive income under SJV conditions. Mechanical hedging alone generated the greatest gross income, lowest cost of application and the greatest positive income per hectare.

Conclusions

The results presented in this study show the effects of vineyard mechanization on canopy microclimate and its consequential effects on yield components and efficiency, while providing labor cost savings. In warm regions where the economic pressure for production per hectare is high with a declining labor pool the methods identified in this trial present an opportunity for growers to optimize crop load without adversely affecting fruit composition and pruning weight while saving labor operation costs.

Mechanical shoot thinning provided higher level of control of canopy microclimate promoting vine balance and production. Based on these results growers would be able to alter the yield to an economic yield threshold of 12 tons/A while achieving a Ravaz Index of 10-12 without adversely affecting pruning weight or fruit composition in a warm climate.

We conclude that mechanical hedging previous year's canes to a 4 inch spur height and shoot thinning to a density of 11 shoots/ft resulted in balanced vines with consistent production. Leaf removal, while beneficial in reducing canopy leaf layers and improving percent gaps within the canopy did not demonstrate any beneficial effects on yield components or fruit composition. Leaf removal would not be recommended based on these results and it adds an additional cost for the vineyard owner. The precise role of mechanical canopy and crop load manipulation will be better understood once their collective influence on wine chemistry on Pinot gris is further examined.

Literature cited

- California Department of Food and Agriculture. 2012. Grape crush report Final 2011. Sacramento. 1 April 2012 http://www.nass.usda.gov/Statistics_by_State/California
- Coombe, B.C. 1995. Adoption of a system for identifying grapevine growth stages. *Aust. J. Grape Wine Res.* 1:104-110.
- Gladstone, E.A., and N.K. Dokoozlian. 2003. Influence of leaf area density and trellis/training systems on the microclimate within grapevine canopies. *Vitis* 42:123-131.
- Howell, S.G. 2001. Sustainable grape productivity and growth-yield relationship: A review. *Am. J. Enol. Vitic.* 52:165-174.
- Kliewer, W.M., and N.K. Dokoozlian. 2005. Leaf Area/Crop weight ratios of grapevines: Influence on fruit composition and wine quality. *Am. J. Enol. Vitic.* 56: 170-181
- Kurtural, S. K., G. Dervishian and R. L. Wample. 2012. Mechanical canopy management reduces labor costs and maintains fruit composition in Cabernet Sauvignon grape production. *HortTechnology*. 22: *in press*
- Morris, J. 2007. Development and commercialization of a complete vineyard mechanization system. *HortTechnology* 17: 411-421.
- Poni, S., F. Bernizzoni, P. Presutto, and B. Rebucci. 2004. Performance of Croatina under short-cane mechanical hedging: A successful case of adaptation. *Am. J. Enol. Vitic.* 55: 379-388.
- Peacock, W., S. J. Vasquez, J.M. Hashim, G.M. Keavitt, K.M. Klonsky and R.L. Demoura. 2005. Sample costs to establish and produce wine grapes. University of California Cooperative Extension. GR0SJ-05-R. Davis, CA
- Terry, D.B., and S.K. Kurtural. 2011. Achieving vine balance of Syrah with mechanical canopy management and regulated deficit irrigation. *Am. J. Enol. Vitic.* 62: 426-437

Denele Respiration Rate (D.R.R.)

Joe Mullinax, Plant Pathologist, Denele Analytical, Inc.
Environmental and Agricultural Analysis,
1232 South Avenue, Turlock, CA 95380;
phone: (209) 634-9055;
Email: deneleanalytical@yahoo.com

Soil nitrogen release rate has been an elusive measurement for years. We commonly don't calculate it, leading to over or under fertilization, or we estimate by non-reliable methods.

D.R.R. now provides us with an inexpensive, repeatable method to analyze soils based on the Solvita Soil Microburst method. Calculations and changes were required in order to tailor the method to west coast soil conditions and types. We had to compensate for the release of CO₂ from sterile soil, and adjust the soil temperature to 68°F to mimic our soil conditions. The nitrogen release rate calculation was compared to empirical numbers over three years and adjusted.

We now have a reliable, inexpensive, repeatable test to measure microbial activity, available carbon, and nitrogen release rate.

NOTES & QUESTIONS

Sorghum for Forages and Biofuel: Breeding and Improvement

Jeff A. Dahlberg, Director, UC-ANR Kearney Agricultural Research and Extension Center,
9240 S. Riverbend Avenue, Parlier, CA 93648
Phone (559) 646-6060, FAX (559) 646-6015, jadahlberg@ucanr.edu

Peggy G. Lemaux, UCCE Specialist, Dept. Plant & Microbial Biology,
111 Koshland Hall, University of California, Berkeley, CA 94720
Phone (510) 642-1589, lemauxpg@berkeley.edu

Bill Orts, Research Leader, USDA-ARS Western Regional Research Center,
800 Buchanan St., Albany, CA 94710
Phone (510) 559-5730, bill.orts@ars.usda.gov

Bob Hutmacher, Director, UC-ANR West Side Research & Extension Center,
P. O. Box 158 17353 West Oakland Avenue Five Points, CA 93624-0158
Phone (559) 884-2411 Fax (559) 884-2216, rbhutmacher@ucdavis.edu

Steve Wright, Farm Advisor, UCCE Tulare/Kings Counties,
4437 S. Laspina St., Suite B, Tulare, CA 93274-9537
Phone (559) 684-3315, Fax (559) 685-3319, sdwright@ucdavis.edu

Sally Thompson, Assistant Professor, Civil & Environmental Engineering,
661 Davis Hall, University of California, Berkeley, CA 94720
Phone (510) 642-1980, thompson@ce.berkeley.edu

Daniel Putnam, Agronomist, Dept. of Plant Sciences,
University of California, Davis, 2240 PES, Davis, CA 95616
Phone (530) 752-8982, dtputnam@ucdavis.edu

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important cereal crop in terms of world production and is a globally important crop (FAOSTAT, 2013). The United States is the world's largest sorghum producer and the majority of US sorghum production is in Kansas and Texas, with only limited production in California (USDA NASS, 2013). Despite its limited production in the state, sorghum is a useful rotation crop. It remains productive under comparatively low water, higher saline, and nutrient conditions (Marsalis and Bean, 2010), and also produces biomass that is well suited for the production of biofuels feedstock and livestock feed (Marsalis and Bean, 2010). Sorghum also produces grain that can be used in food production or as feedstock for ethanol production. Sorghum could therefore help reduce irrigation and nitrogen fertilizer use in California while diversifying cropping systems in the state and producing valuable food, animal, and renewable feedstocks.

Forage Sorghum for Animal Feed

Research has shown that sorghum forages can routinely utilize $\frac{1}{2}$ to $\frac{1}{3}$ the water of corn forage and still maintain excellent nutritional quality for animals (Hutmacher and Wright, 2011;

Bean and Marsalis, 2012). Forage sorghum has shown promise in the San Joaquin valley, but little information is available to farmers that showcase the potential of sorghum forages to meet the demands of this industry. In 2011, over 80 commercially available sorghum forages were evaluated for both yield and quality parameters in large replicated trials in two locations in California. These test results indicate that sorghum forages do have the yield and the quality to meet the needs of dairy farms in the San Joaquin valley. It is also quite clear that additional research is needed to identify the proper planting dates, densities, fertilization, and water that will optimize sorghum forage yields and quality without lodging issues. Forage selection should be a combination of factors that optimize quality, yield and standability and further research should identify those forages that will benefit the farmers of California.



White and brown durra sorghums were first introduced to California in 1874 as animal feed; however, genetic improvement of forage sorghums was not as important as grain sorghum. Extensive breeding programs to improve forage sorghum are relatively new, within the last 25 years, and considerable progress has been achieved to improve forage quality, yield, and standability. Many of the older, standard cultivars have been replaced by hybrid forages with new genetics, such as

photoperiodism, bmr, and improved nutritional qualities. BMR was first chemically induced in sorghum by Porter et al. (1978) and its impact on quality has been one of the major driving forces in creating sorghums that are equivalent to the standard of corn in nutritional value (Pedersen and Fritz, 2000). BMR sorghums have lower lignin than normal genotypes and one of the major drawbacks of bmr has been lodging. Recent genetics controlling internode length, called brachytic forages offer promising lodging resistance that will improve standability in bmr sorghums and increase the digestibility of forage sorghums overall as these genetics are moved into a greater number of forage sorghums.

Sorghum as a Biofuel Crop

Sorghum is unique in that it can be used in all the various processes being discussed and debated for biofuel production - starch-to-ethanol, sugar-to-ethanol, and cellulosic and lignocellulosic-to-biofuel. Research on the use of sorghum grain (Sweeten et al., 1983; Wang et al., 2008), the use of sweet sorghum (Worley et al., 1992; Tew et al., 2008), and recent research on its utility as a biomass feedstock for cellulosic/lignocellulosic fuel production (Dahlberg et al., 2011), showcases the potential of sorghum as a leading renewable feedstock. Sorghum has long-running sorghum R&D programs and seed suppliers that already exist, and the general agronomy for the species is well established.



Sorghum grain is also suitable for the production of ethanol, with ethanol yields per ton of grain being similar to that of corn (Wang et al., 2008). Under ideal conditions the total grain yield of sorghum is generally less than that of corn; however, because sorghum can remain productive under lower input conditions or higher saline conditions, it may be a more suitable grain-ethanol crop in California under circumstances of low irrigation and fertilization. Sweet sorghum is a specialty sorghum that, like sugarcane, can be processed to produce sugar, which can then be used directly for ethanol production.

Work is underway to evaluate the potential of sweet sorghum in California through various production trials.

Yield traits, insect and disease genetics and other important genes for improvement can readily be moved from sorghum germplasm into bioenergy sorghums. Recent advances in NIR technology are allowing sorghum breeders to tailor high biomass sorghums to fit various compositional characteristics that will optimize the sorghum for fuel output. Dahlberg et al. (2011) showed that, using available commercial forage hybrids and based upon theoretical yield calculations using DOE models, sorghum currently can produce over 850 gal acre⁻¹ of ethanol as a biomass feedstock. Recent work is showing germplasm capable of increasing these figures by 500 gal acre⁻¹.

Clearly, as both a forage feedstock for animal feed and as a biomass feedstock, sorghum presents an attractive addition to many cropping systems that are in use in California. With its innate ability to tolerate a high level of water and heat stress, its lower costs, and its use of fewer inputs, sorghum can and should play an important role in the agricultural landscape of California.

Literature Cited

- Bean, B. and M. Marsalis. 2012. Corn and sorghum silage production considerations. Proc. High Plains Dairy Conference, Amarillo, TX.
- Dahlberg, J., J. Berenji, V. Sikora, and D. Latkovic. 2011. Assessing sorghum [*Sorghum bicolor* (L) Moench] germplasm for new traits: food, fuels & unique uses. *Maydica*, 56:165-172.
- Dahlberg, J., E. Wolfrum, B. Bean, and W. L. Rooney. 2011. Compositional and agronomic evaluation of sorghum biomass as a potential feedstock for renewable fuels. *Journal of Biobased Materials and Bioenergy*. 5:507-513.
- FAOSTAT. 2013. FAOSTAT <http://faostat.fao.org/site/291/default.aspx>. [cited 2013 January].
- Hutmacher, R. and S. Wright. 2011. Irrigation of silage sorghum in California. American Society of Agronomy, California Plant and Soil Conference, Jan. 2011.
- Pedersen, J. E. and J. O. Fritz. 2000. Forages and Fodder. p. 797-810. In C. W. Smith and R. A. Frederiksen (eds.) *Sorghum: origin, history, technology, and production*. John Wiley & Sons, Inc. New York, NY.

- Porter, K., S., J. D. Axtell, V. L. Lechtenberg and V. F. Colenbrander. 1978. Phenotype, fiber composition, and in vitro dry matter disappearance of chemically induced brown midrib (bmr) mutants of sorghum. *Crop Sci.* 18:205-208.
- Marsalis, M.A. and B. Bean. 2010. United sorghum checkoff program: Western forage production guide, J. Dahlberg, E. Roemer, J. Casten, G. Kilgore, and J. Vorderstrasse (eds), Lubbock, TX. p. 63.
- Sweeten, J.M., C.G. Coble, and R.P. Egg. 1983. The use of grain sorghum in integrated food and fuel production systems., p. 63-73. In *Alternative Energy Sources V. Part D: Biomass/Hydrocarbons/Hydrogen.*, T.N. Veziroglu (eds.), Elsevier Science Pub., Amsterdam.
- Tew, T.L., R.M. Cobill, and E.P. Richard Jr. 2008. Evaluation of sweet sorghum and sorghum x sudangrass hybrids as feedstocks for ethanol production. *BioEnergy Research*, 1:147-152.
- USDA NASS. 2013. National Agricultural Statistics Service <http://www.nass.usda.gov/>. [cited 2013 January].
- Wang, D., S. Bean, J. McLaren, P. Seib, R. Madl, M. Tuinstra, Y. Shi, M. Linz, X. Wu, and R. Zhao. 2008. Grain sorghum is a viable feedstock for ethanol production. *J. Ind. Microbiol. Biotechnol.*, 35:313-320.
- Worley, J.W., D.H. Vaughan, and J.S. Cundiff. 1992. Energy Analysis of Ethanol Production from Sweet Sorghum. *Bioresource Technology*, 40:263-271.

Developing Objective Analyses to Aid in Breeding Almonds for Kernel Quality

Craig Ledbetter, Ph.D, USDA-ARS,
Crop Diseases, Pests and Genetics Laboratory, Parlier, CA 93648;
phone: (559) 596-2817; e-mail: Craig.ledbetter@ars.usda.gov

Please contact the presenter for more information related to this topic

NOTES & QUESTIONS

Screening and Selection for Fusarium Race 4 Resistance in Cotton

Robert B. Hutmacher, CE Specialist and Center Director,
UC-ANR West Side Research & Extension Center,
P. O. Box 158 17353 West Oakland Avenue Five Points, CA 93624-0158
Phone (559) 260-8957 Fax (559) 884-2216, rbhutmacher@ucdavis.edu

Steve Wright, Farm Advisor, UCCE Tulare/Kings Counties,
4437 S. Laspina St., Suite B, Tulare, CA 93274-9537
Phone (559) 684-3315, Fax (559) 685-3319, sdwright@ucdavis.edu

Introduction

In California, Fusarium wilt of cotton has been considered a potentially serious fungal disease caused by the organism *Fusarium oxysporum* *var infectum* (also called “FOV”). However, in the past, damage associated with Fusarium in SJV cotton has been notable only in production areas with the combination of: (a) moderate to high populations of a specific race of FOV (usually race 1); (b) soils with a sandy or sandy loam texture; and (c) root knot nematodes present in high-enough populations to cause significant galling and root damage. Past research generally indicated that FOV damage was worst when both FOV inoculum and nematodes were present in relatively high concentrations. Methods used in the past to limit damage to cotton associated with Fusarium wilt have been to avoid planting cotton in soils in which the combination of sandy or sandy loam texture is combined with the presence of root knot nematode, or grow cotton only infrequently as part of a crop rotation that includes crops less likely to build soil inoculum loads. The race 4 FOV can be clearly identified as different from Australian FOV races and different from the most-studied Fusarium species in cotton (mostly races 1, to lesser extent race 3) prevalent in sandy loam soils and problem areas of the SJV for decades.

This research has been directed toward field evaluations in a race 4 Fusarium resistance screening program that includes:

- (a) commercially-available germplasm;
- (b) experimental cultivars from company commercial development programs;
- (c) entries from cotton breeders across the U.S. cotton producing states, including those from the Regional Breeder Tests coordinated through Cotton Incorporated, plus efforts continue to solicit entries from private company breeders working with Pima or hybrids; and
- (d) entries from the USDA-ARS germplasm collection and specific FOV race 4 selections

Efforts in field germplasm screening for Fusarium resistance began in 2003 and continue currently in multiple field sites found to be infested with this pathogen, plus evaluations done at the University of CA Kearney Agricultural Research and Extension Center. University of CA Davis Plant Pathologist Dr. Michael Davis and his graduate students have been involved in identification of disease organisms in all these evaluations in support of FOV race identification needed as part of continuing investigations, and in providing inoculum for greenhouse screening trials.

Summary of FOV Race 4 Screening Efforts

Field varietal screens were done in grower fields confirmed to be infested with FOV race 4. The field tests were done only in parts of fields where a prior cotton crop showed consistent, significant plant losses due to FOV race 4 (greater than 30 percent mortality in susceptible Pima cotton entries). An initial plant population count was done within 2 weeks after planting in plots, followed by plant survival counts done a minimum of two times during an evaluation period of 7-8 weeks after emergence of cultivars being tested for resistance. In addition to plant survival percentages, we also evaluated plants for root vascular staining, foliar damage index rating, and plant size / height and node counts as a measure of vigor.

In greenhouse pathogenicity tests, cotton seedlings with 1 to 3 true leaves were root dip-inoculated in a conidial suspension of 6×10^5 spores/ml for 3 minutes. Plants were then transplanted into heat-treated potting soil mix into 8 cm square by 20 cm deep pots and grown in a temperature-controlled greenhouse for a minimum of 3 to 4 weeks to allow time for disease and symptom development. Plant assessments were made at that time to determine the timing for destructive plant evaluations, and any plants with severe symptoms were assessed and sampled prior to plant death from the disease. After approximately 6 to 8 weeks, all remaining plants were removed from pots by pulling up plants and cutting the tap root at 2-3 cm below the soil line. The vasculature near the soil line and distal several centimeters of stem were examined for vascular staining (discoloration) typical of Fusarium wilt. Efforts to date have focused on a mix of Acala and non-Acala Uplands and commercial Pima varieties of interest to California commercial cotton producers and seed producers, plus some experimental materials both from public and private sources.

Since long-term management of Fusarium wilt relies on the development of resistant varieties, efforts focus on screens of cultivars from a wide range of cotton seed companies, in order to get a broad germplasm base. Early greenhouse tests of the pathogen isolated from these fields indicated that several Pima varieties tested were infected at a higher rate and damaged much more seriously than several Acala varieties evaluated in the same greenhouse tests. Subsequent tests conducted both in the field and greenhouse inoculated trials have been consistent in clearly showing that many Acala and non-Acala varieties can also be infected by this race of FOV, albeit with significantly less plant damage than in most Pima varieties tested to date. In general, in fact, it has been difficult to find Upland varieties that are as resistant and lightly affected as resistant Pima varieties when placed under moderate to high inoculum pressure. Germplasm highly-resistant to FOV race 4 were identified in Pima at the inoculum levels tested under greenhouse conditions and levels found in multiple infected field test sites. Germplasm evaluations to date can be summarized as follows: (1) most Pima varieties show more severe symptoms and suffer higher levels of stunting and plant mortality than Acala/Uplands; (2) several highly-resistant commercial Pima varieties and about a half dozen USDA-ARS/Univ. CA experimental cultivars have been identified at evaluations done at multiple sites; and (3) most Acala / Upland germplasm tested, while less severely impacted than most Pima varieties, were infected by the race 4 FOV when present in soil at infested field sites or when inoculated in greenhouse trials. We have repeatedly identified locations in 2011 field evaluations where FOV inoculum levels have increased to levels inflicting serious plant damage and significant plant losses (>25% plant losses) in both Upland/Acala cotton fields and Pima cotton fields, and have confirmed that inoculum levels can build to damaging levels even when

only Upland cotton has been grown in prior years (no prior history of growing the more susceptible cultivars of Pima).

Results from our studies can be utilized in further genetic evaluations and to identify sources of host plant resistance useful to growers and breeders. Development of host-plant resistance is currently considered the most economic and effective strategy for managing FOV in California cotton production regions. Since long-term management of Fusarium wilt relies on the development of resistant varieties, efforts have focused on screens of cultivars from a wide range of cotton seed companies, and in addition, we are now including entries from the Regional Breeder trials (RBTN studies representing Upland entries from around the U.S. cotton belt. In general, to date in our screening evaluations, it has been difficult to find Upland varieties that are as resistant and lightly affected as resistant Pima varieties when placed under moderate to high inoculum pressure. Germplasm highly-resistant to FOV race 4 were identified in Pima at the inoculum levels tested under greenhouse conditions and levels found in multiple infected field test sites. Further field and greenhouse evaluations of a range of Acala and Pima varieties will continue as long as entries are available and project funding from one or more sources is available for this program.

Results of the screening work done in prior years are available in the “Variety Trials” section of the University of CA Cotton web site: <http://cottoninfo.ucdavis.edu>. Look under “variety trials by year” in the website, and follow down to Field and Greenhouse FOV screening to view summaries from the 2009 through 2011 growing seasons. When available and summarized, we will post the 2012 screening results in this same section of the UC cotton web site.

References

- Bell, A.A. 1984. Cotton protection practices in the USA and world. Section B: Diseases. P. 288-309. In R.J. Kohel and C.F. Lewis (ed), Cotton, Agronomy Monograph 24. ASSA, Madison, WI.
- Bennett, R.S., R.B. Hutmacher, and R. M. Davis. 2008. Seed Transmission of *Fusarium oxysporum* f. sp. *vasinfectum* Race 4 in California. J. Cotton Science. 12: 160-164.
- Garber, R.H., and G.A. Paxman. 1963. Fusarium wilt of cotton in California. Plant Disease Reporter 47: 398-400.
- Gilbert, C.A., N. Zhang, R.B. Hutmacher, R. M. Davis, and C.D. Smart. 2008. Development of a DNA-based Macroarray for the Detection and Identification of *Fusarium oxysporum* f. sp. *vasinfectum* in cotton tissue. J. Cotton Science 12:165-170.
- Hutmacher, R.B., R.M. Davis, M. Ulloa, S.D. Wright, D.S. Munk, R.N. Vargas, B.A. Roberts, B.H. Marsh, M.P. Keeley, Y. Kim, and R.G. Percy. 2005. Fusarium in Acala and Pima cotton: Symptoms and Disease Development. P. 245-246. In: J.Brown (ed), Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN.
- Kim, Y., R.B. Hutmacher, and R.M. Davis. 2005. Characterization of California Isolates of *Fusarium oxysporum* f. sp. *Vasinfectum*. Plant Disease 89:366-372.
- Ulloa, M., R.B. Hutmacher, R.M. Davis, S.D. Wright, and R. Percy. 2006. Breeding for Fusarium wilt Race 4 resistance in cotton under field and green house conditions. J. Cot. Sci. 10: 114-127.
- Ulloa, M., R. Percy, J. Zhang, R.B. Hutmacher, S.D. Wright, and R. M. Davis. 2009. Registration of four Pima cotton germplasm lines having good levels of Fusarium wilt race 4 resistance with moderate yields and good fibers. J. Plant Registr. 3(2): 198-202.



American Society of Agronomy

California Chapter

Session V
Water Management

Session Chairs:

Florence Cassel- Sharma

Allan Fulton

Soil Moisture Sensor Phase II Virtual Test for Irrigation Association

Diganta D. Adhikari, David F. Zoldoske, Edward M. Norum, and Joe Oliphant

Center for Irrigation Technology, California State University Fresno

5370 N. Chestnut Ave. M/S OF 18

Fresno, CA 93740-8021

Phone: (559) 278-2066 Fax: (559) 278-6033

Emails: diganta@csufresno.edu , davidzo@csufresno.edu , edwardn@csufresno.edu and joeo@csufresno.edu

Abstract

The Irrigation Association (IA) through its Smart Water Applied Technology (SWAT) effort has been working for the last decade to develop an independent third party testing protocol designed to evaluate control systems that “automatically” adjust irrigation events using either soil moisture sensors (SMS) or climatologically-based controllers. After extensive review and public comments recently, a second testing protocol has been developed, which links SMS response curves to a controller in managing irrigation schedules for six different virtual landscape zones. This protocol is designed to provide a similar test and evaluation method as established with the “Smart” climatologically-based controllers. It is hoped that the performance results of the two different operational platforms can be compared directly. This presentation will discuss the methods and outcomes derived from utilizing the new IA protocol based on SMS response curves as well as issues of compatibility of the “computer interface” used for this test.

Introduction

The overall goal of this project was to verify the efficacy of the IA Soil Moisture Sensor Phase II-Virtual Landscape test. In particular, this project focused on the application of standardized testing protocols on soil moisture sensors operating on different principles (Phase I) and translated it for Phase II Virtual Landscape testing. The evaluation concept used accepted formulas for calculating crop evapotranspiration (ET_c) and a weather station on site to estimate the moisture balance, which was used by the controller to achieve efficient irrigation while minimizing potential runoff. There are allowances in this evaluation for variability in soil properties and the inherent problems associated with trying to characterize these problems to scientific instruments.

Proposed Work and Statement of Methodology

Participating manufacturers were required to submit a controller and/or controller interface module along with a data conversion device (computer interface). The data conversion device acted as the interface that accepted the most recent moisture data from the CIT monitoring computer and converted it to a format accepted by the manufacturer’s controller under test (see additional details at www.irrigationorg/gov/swat_drafts-soil/).

The Phase II-Virtual landscape included six zones to accommodate a variety of soils, water quality, plant material, slope, temperature, exposure to sun, root zone storage, precipitation rate, application efficiency, and area. The individual zones within the landscape represented a combination of the factors stated above to represent a range of agronomic conditions.

The total accumulated moisture deficit over time was used to measure adequacy while the accumulated surplus of applied water over time provided the system efficiency. Any water applied above the soil water holding capacity was characterized as runoff or deep percolation, which lowers application efficiency.

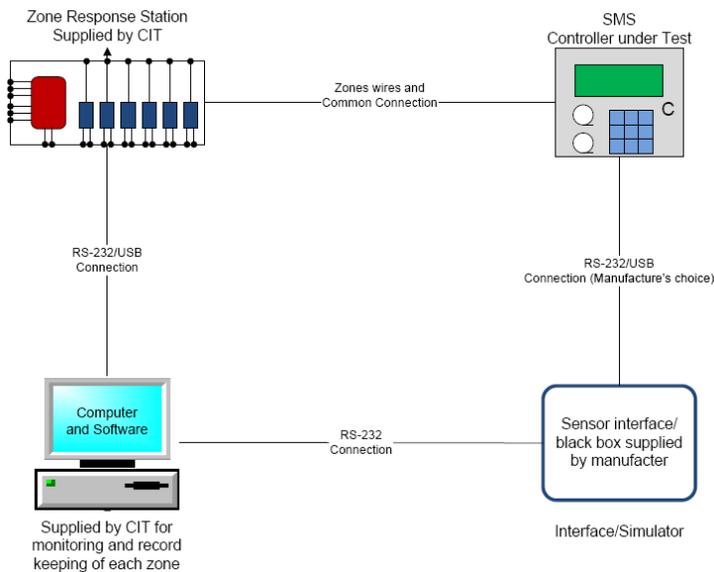
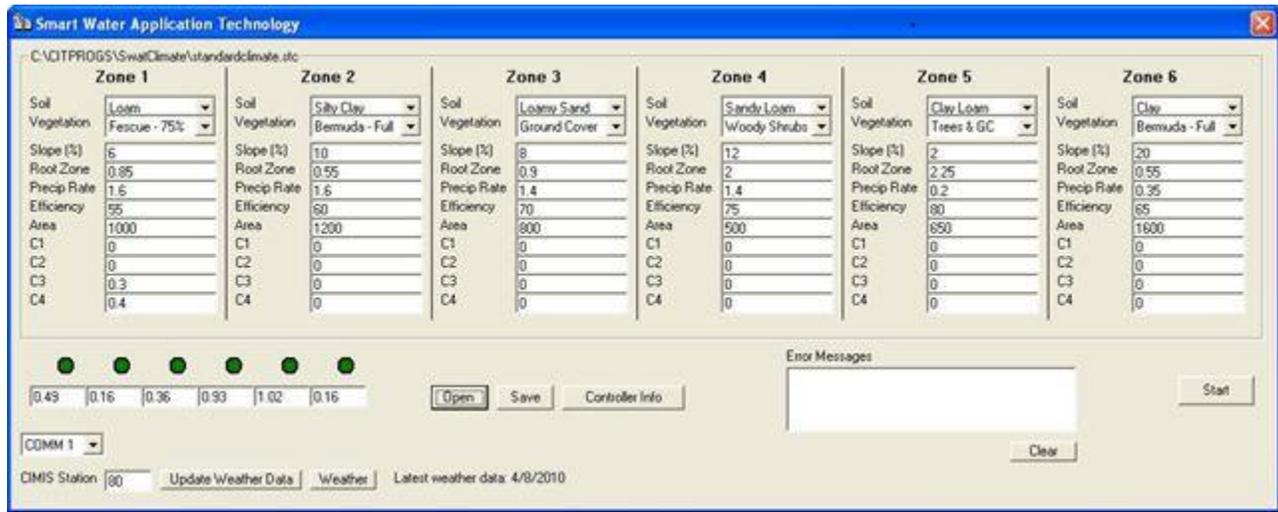


Figure 1: Schematics and layout of the Phase-II testing.

Results

Controllers from three manufacturers with different SMS operating principles were successfully tested during this beta testing phase and the following data ranges were recorded. (Given the complexities of the test development and small testing sample, it is premature to make comparisons between these beta testing results and results obtained using climatologically based controllers.)

- Irrigation Adequacy: 100 to 73.8 %
- Scheduling Efficiency: 100 to 25%
- Overall Efficiency: 100 to 70%
- Rainfall Efficiency: 100 to 80%

Irrigation Association - Smart Water Application Technology Soil Moisture Sensor Based Controllers

International Center for Water Technology

Project Identification	Manufacturer	Black Box 1
	Model Number	
	Serial Number	
	Evaluated By	JC
	Date	October 1, 2010 - October 30, 2010
	Weather Station	CIMIS 80
	Reference No.	
	Comments	

Parameter	Zone #1	Zone #2	Zone #3	Zone #4	Zone #5	Zone #6
Soil Type	Loam	Silty Clay	Loamy Sand	Sandy Loam	Clay Loam	Clay
Vegetation	Fescue - 75%	Bermuda - Full	Ground Cover	Woody Shrubs	Trees & GC	Bermuda - Full
Slope, %	8.0	10.0	8.0	12.0	2.0	20.0
Root Zone Stor., in.	0.85	0.55	0.90	2.00	2.25	0.55
Precip Rate, in./h	1.50	1.60	1.40	1.40	0.20	0.35
Efficiency, %	85	80	70	75	80	85
Area, SQ-Ft	1000	1200	800	800	650	1800
Soil Intake Rate, in./h	0.35	0.15	0.50	0.40	0.20	0.10
AGA, in.	0.25	0.16	0.26	0.24	0.28	0.10
Max. Run Time, min.	12.0	6.8	17.0	14.4	N/A	24.0

Parameter	Zone #1	Zone #2	Zone #3	Zone #4	Zone #5	Zone #6
ETc, in.	3.64	3.64	3.64	3.64	3.64	3.64
ETe, in.	1.79	2.21	1.98	1.43	2.28	2.21
Gross Rainfall, in.	0.64	0.64	0.64	0.64	0.64	0.64
Net Rainfall, in.	0.52	0.52	0.52	0.52	0.52	0.52
Eff. Rainfall, in.	0.52	0.52	0.52	0.52	0.43	0.52
Gross Irr., in.	2.82	1.84	2.59	2.03	8.06	1.89
Direct Runoff, in.	0.00	0.00	0.00	0.00	0.00	0.00
Soak Runoff, in.	0.08	0.06	0.07	0.07	0.00	0.05
Effective Irr., in.	1.38	1.07	1.80	1.40	6.38	0.99
Deficit, in.	0.00	0.46	0.00	0.00	0.00	0.58
Surplus, in.	0.00	0.00	0.00	0.00	3.51	0.00
Irr. Adequacy, %	100.0	79.1	100.0	100.0	100.0	73.8
Sch. Eff., %	94.4	94.6	95.2	95.2	44.9	95.1
Overall Eff., %	51.9	56.8	67.4	71.4	35.9	61.8
Rainfall Eff., %	100.0	100.0	100.0	100.0	82.7	100.0
Cur. Moist. Bal., in.	0.61	0.18	0.71	1.61	2.28	0.18

Figure 2: A typical layout of a performance report.

Conclusion

The Phase II-Virtual Landscape testing technique reduced the testing time to 30 days, or until the minimum rainfall requirement of 0.4 inches and reference ETo of 2.5 inches were met. This could potentially save a considerable amount of time and energy compared to the conventional outdoor irrigation controller tests performed using real vegetative conditions. Further, this model of testing allows for most of the conditions except for ETo and rainfall, to be replicated each time and around the year for the different controllers being tested.

During this phase of testing we were able to resolve/address all the issues related to compatibility of the computer interface and a standardized description for the computer interface and the communication protocol was finalized for future reference. Now that we have a better understanding of how the entire process works, future testing can be conducted using the latest protocol (see the full draft protocol posted at the IA website for additional details).

Integrating Soil Moisture Monitoring into Irrigation Management

Bruce Ferri

Almond Grower and CSU, Fresno Graduate Student

7424 N Laguna Vista Ave, Fresno, CA 93711

559-287-8332; bruce@yorkfamilyfarms.com

Introduction

Many almond growers in California's central San Joaquin Valley do not have deep-water wells and only have limited access to irrigation water. Additionally, while it is true that many California almond growers have access to higher quality surface water from irrigation districts, many other orchards, especially on the west side of San Joaquin Valley only have limited access to lower quality irrigation water sources. They have to allocate many resources, including time, money and physical effort, to deal with their water availability issues and irrigation management. With increasing electric costs, water availability and regulations, whatever we can do to better manage our resources will benefit growers and the community.

Background

I farm 450 acres of almonds about 3 miles north of Helm, CA. I do not have access to surface water and must rely on my four 250hp wells to irrigate the crop. While I have 9 different soil types at the orchard, ranging from fine sandy loam to clay loam, but it is primarily temple loam. Prior to installing our first 4 PureSense monitoring stations in late 2010, we managed our irrigation scheduling like most other growers – we would start the wells Friday evening and turn them off Monday morning. This was not efficient and was very expensive. I realized I had to get serious. I began using 4 stations in early 2011, 1 per block (85-120 acres per block). After a few months, I realized that I was overwatering some areas and under watering others. I then installed 3 additional stations in 2012 and now manage in 40-acre blocks.

Field Monitoring Station - The FMS collects real-time data from my orchard by monitoring soil and climate conditions every 15 minutes. The FMS consists of:

- Mini on-board field computer that stores and relays data to PureSense servers via a cellular modem.
- Weather station collects accurate weather data describing local conditions in my orchard. Records the in/out of canopy temperature and humidity, wind speed and direction, rainfall totals and solar radiation for evapotranspiration (ET).
- Pressure switch on the drip line that tracks the inches of irrigation water applied and the duration and timing of irrigation events. I am then able to confirm timing and duration of irrigation events and automatically maintain detailed records.
- Soil monitoring probes that measure soil moisture, soil temperature and salinity. Installed at depths every 12 inches down to 60 inches, these probes continuously monitor plant-available water and provide below-ground visibility so I can maintain ideal moisture conditions.
- A solar panel recharges the battery that powers the FMS. This independent power supply enables the FMS to be placed in the ideal field, orchard or vineyard location for accurate irrigation decisions.

Innovative Software - Software: Irrigation Manager™ and Mobile Manager™

Irrigation Manager is the software powering the PureSense solution. It provides me with real-time access to their field data. Mobile Manager is the Web-browser enabled version of Irrigation Manger accessible from my iPhone and iPad.

This allows me to both manage irrigation scheduling and irrigation planning through a secure online access through a password-protected login makes the PureSense application available from anywhere at anytime. I have a personalized dashboard that offer an on-screen snapshot of moisture levels, climate conditions and irrigation requirements making critical information easy to access and understand. I also have access to reports and charts summarize soil moisture, climate and irrigation system information to help guide grower decisions and provide a record over multiple seasons. The best feature is the irrigation planning that helps me budget based on local evapotranspiration data and related crop coefficient. I also receive custom alerts for frost and moisture levels via email and cell phone. These notifications give me the opportunity to immediately respond to critical conditions in their fields. Other features include heat hours, chill hours and degree-days are tracked in charts and reports so I can monitor disease risk factors, manage plant health and schedule cultural practices, such as pest control.

Tree Solutions - PureSense gives me the ability to:

- Maintain my deep water bank – helps ensure that I establish a deep water profile early in the growing season and maintain this during fruit development, so my trees always has access to ample available water.
- Ensure frost protection – receive alerts on my cell phone when temperatures drop low enough to require action.
- Mitigate hull rot – implement safe and effective regulated deficit irrigation to minimize in-canopy humidity without stressing my trees.
- Maximize nut size – accurately meet plant-water requirements during nut fill to drive maximum nut quality and yield.
- Improve management control – easily track irrigation times and inches of applied water to ensure irrigation timing is being accurately followed.
- Precisely manage pre- and post-harvest irrigation – ensure effective dry down and recovery to maintain plant health.

Benefits Realized

- Reduced energy and water costs
- Decreased disease pressure
- Increased frost protection
- Increased yields

Literature Cited

PureSense – <http://puresense.com>

CropManage – A Web-based Irrigation and Nitrogen Management Tool

Michael Cahn, UC Cooperative Extension, Monterey County
1432 Abbott St, Salinas CA 93901
Phone 831-759-7377, FAX 831-758-3018, mdcahn@ucdavis.edu

Richard Smith, UC Cooperative Extension, Monterey County
1432 Abbott St, Salinas CA 93901
Phone 831-759-7357, FAX 831-758-3018, rifsmith@ucdavis.edu

Tim Hartz, Dept. of Plant Science
One Shields Avenue, Davis, CA 95616-8780
Phone 530-752-1738, tkhartz@ucdavis.edu

Background

Commercial lettuce production traditionally uses high inputs of nitrogen (N) fertilizer and water to maximize yield and quality. Changes in water quality regulations on the Central Coast and spikes in fertilizer prices in recent years have prompted grower interest in increasing efficiency of nitrogen fertilizer use in lettuce. Lettuce growers could potentially use less N fertilizer and address water quality concerns by improving water management and matching nitrogen applications to the N uptake pattern of the crop. Two tools available to growers, the quick nitrate soil test (QNST) and evapotranspiration (ET) data from the California Irrigation Management Information System (CIMIS), have been shown to help better manage water and fertilizer nitrogen in lettuce production (Cahn and Smith 2012, Hartz et al. 2000). However, adoption of these practices has not been wide spread.

One reason is that these techniques can be time consuming to use, and vegetable growers have many fields for which they make daily decisions on fertilization, irrigation, pest control, and tillage. The QNST entails collecting a representative soil sample, extracting the sample, and calculating soil mineral N concentration. When deciding on an appropriate N fertilizer rate, growers also need to consider the N uptake rate of the crop, and mineral N contributions from soil and previous crop residues. Scheduling irrigations based on weather requires retrieving reference ET data from the CIMIS website, and determining an accurate crop coefficient that corresponds to the developmental stage of the crop. In addition, information on the soil water holding capacity and irrigation system performance is needed to determine the optimal irrigation interval and run-time. These calculations can be time consuming and often confusing for growers and consultants to integrate into an irrigation schedule.

To address many of the time constraints in managing water and fertilizer, we developed an online tool that assists growers and farm managers with determining appropriate water and nitrogen fertilizer applications on a field-by-field basis. The software automates steps required to calculate crop water needs from CIMIS ET data, and estimates fertilizer N needs for lettuce using quick N test data and models of crop N uptake. The web application also helps growers track irrigation schedules and nitrogen fertilizer applications on multiple fields and allows users from the same farming operations to view and share records.

Software description

In collaboration with UC Agriculture and Natural Resources (UCANR), Communication Services personnel, we launched a preliminary version of a web-based software program for managing nitrogen and water in lettuce production on Sept 1, 2011. The software application, named CropManage (ucanr.org/cropmanage), is hosted and maintained on the UCANR Communications server in Davis, CA. Using a web browser, users can access the software through smart phones, tablet and desktop computers.

CropManage was designed to be intuitive for growers and farm managers to use. The user interface and menu structure were designed and developed under the oversight of collaborating growers, and follows common practices that they use to maintain records of fertilizers, soil tests, and irrigation.

The web application uses a secure login procedure so that only individuals with permission can view and/or edit water and nitrogen fertilizer records of a particular farming operation. After logging on, a screen displays a list of ranches/farms that the user has permission to access. By following the hyperlink for an individual ranch, the user can view a list of all active and/or past plantings associated with the ranch.

A database manages information associated with ranches, fields and plantings, which are used to drive the irrigation and N fertilizer models. The database also facilitates combining and displaying data from multiple sources, such as data from user entries, the CIMIS website, and field sensors. It also minimizes the necessity for reentering information. To establish a new ranch, data must initially be uploaded, which includes lists of field names, associated acres and soil types, as well as a list of nearest CIMIS stations. Each ranch in CropManage requires one user to serve as a “virtual farm manager” who has administrative responsibility to grant other users permission to view and/or edit ranch data and also to customize settings for the ranch.

To add a planting (new crop) to a ranch, one selects the appropriate field, and enters lettuce type, planting/harvest dates, planted acres, bed spacing, and irrigation system characteristics. The planting “home” screen displays summary tables of soil tests, fertilizer applications, and watering schedules. When the user enters intended dates to fertilize and/or irrigate, the summary tables are updated with recommended fertilizer N rates (Table 1) and water volumes (Table 2). Data in tables can be exported into an excel spreadsheet file.

CropManage also has the option of automatically importing, analyzing, and displaying flow meter data, allowing growers to conveniently track the volume of water applied to their fields. Flow meters capable of producing a voltage pulse output proportional to the flow rate are interfaced with a datalogger that records flow at 2 minute intervals. The dataloggers are equipped with internet accessible cell phones, which permit flow data to be downloaded onto a computer in the Monterey County, Cooperative Extension office. The ANR server in Davis is scheduled to upload and analyze flow meter data files from the county computer four times per day. Because of the complexity involved, we foresee that a service such as an irrigation mobile lab or crop consultant would set up the flow meters in commercial fields for growers.

Nitrogen and water management algorithms for lettuce

In addition to storing and displaying records of soil tests, irrigations, and fertilizations, the software algorithms recommend N fertilizer rates and water applications appropriate for the stage of lettuce growth. The N fertilizer algorithm develops recommendations based on an N uptake curve for lettuce, soil mineral N status (QNST data), as well as estimates of N mineralization from the soil and residue of the previous crop. Future work will incorporate

nitrate-N concentration of the irrigation water into the N fertilizer recommendation. To create a fertilizer recommendation, the user must enter the intended fertilization date, a soil N test value, and estimated days until the next fertilization event. The model uses this information to determine the amount of N fertilizer needed to maintain the soil at a predefined threshold of soil nitrate. The soil nitrate threshold varies from 20 ppm NO₃-N at the early stages of growth to 15 ppm NO₃-N at the late stages.

The irrigation scheduling algorithm uses CIMIS reference ET data, crop coefficient values for lettuce, soil water holding capacity, and the application rate of the irrigation system to estimate the appropriate irrigation interval and volume of water to apply to maximize lettuce growth and minimize deep percolation. The algorithm is based on the canopy model of Gallardo et. al. (1996) for estimating evapotranspiration of lettuce:

$$\text{Canopy cover (\%)} = G_{\text{max}} / (1 + \exp(A + B \times \text{day} / \text{Maxday})) \quad \text{eqn. 1.}$$

where G_{max} is the maximum canopy cover, A and B are fitted parameters in Table 3, day is the number of day after planting and Maxday is the total days between planting and harvest. Parameters for this model were determined for iceberg and romaine lettuce types grown on 40 and 80-inch wide beds by taking overhead near-infra red canopy photos at 10 to 15 day intervals during the crop cycle.

Canopy cover is converted to a crop coefficient (K_c) by a modified version of the equation published by Gallardo et al. (1996):

$$K_c = (0.63 + 1.5 C - 0.0039C^2) / 100 \quad \text{eqn. 2.}$$

where K_c is the crop coefficient, ranging between 0 and 1, and C is percent canopy cover. Evaporation from the soil surface is also estimated by the method described by Gallardo et al. (1996) and used to develop the final K_c value used for estimating crop ET.

To obtain a recommended irrigation volume and interval, the user enters the date of the next irrigation and the software automatically obtains reference ET data from the nearest CIMIS weather station and uses the algorithms described above to estimate the crop coefficient. Historical ET data is used when current data is unavailable. The software also allows the user to select to use reference ET data from spatial CIMIS. Spatial CIMIS reference ET values are partially based on remote sensing estimates of net solar radiation and can provide improved spatial resolution, presumably increasing the accuracy of crop ET estimates for fields located in a different climatic zone than the nearest CIMIS station. The recommended irrigation volume is based on the estimated crop ET adjusted for irrigation system uniformity and leaching fraction, which are initially entered by the user.

Maximum soil moisture tension values known to slow growth of lettuce (-30 kPa) are used to optimize the recommended irrigation interval. The maximum allowable depletion of moisture between irrigations is determined using algorithms relating volumetric soil moisture to soil moisture tension and for estimating rooting depth.

Field validation and demonstration

We tested and demonstrating the CropManage software in 10 commercial lettuce during the 2012 season. Portable flowmeters were installed on the main irrigation pipe in each of these fields so that the grower could view the volume of water applied during individual irrigation

events, and compare actual and recommended volumes of applied water (Fig.1). Participating growers were responsible for monitoring soil nitrate levels of their fields using the quick nitrate test, and entering these values and fertilizer applications amounts into CropManage. Participants provided assessments of the software application that were used to improve the ease-of-use and the functionality of the online tool. We also conducted 2 demonstration trials comparing yield of lettuce grown under standard and CropManage recommended water or nitrogen management practices. One trial comparing the CropManage fertilizer N recommendation with the grower standard practice resulted in similar commercial yields using almost 30% less N fertilizer (Table 4). The other trial comparing the irrigation recommendation of CropManage with the grower standard practice resulted in a 12% savings in water following the CropManage irrigation schedule during the drip phase of the crop, and equal commercial yields between treatments.

Conclusions and future directions

Web-based software appears to be a useful tool for delivering decision support models to growers in a format that they can use for their daily operations, and provides a rapid means to extend new research finds to the agricultural community. Our preliminary work has demonstrated that CropManage could potentially help growers reduce production costs by applying less fertilizer and water, and minimize water quality impacts of vegetable production on surface and ground water supplies. The software tool also provides a convenient means for growers to keep records of their practices, which may help them demonstrate that they are meeting water quality regulatory objectives. Our immediate challenge is to increase the number of commodities included in CropManage so that growers have a tool that can address the full production system on the central coast. As more geo-referenced weather and soil data become available on the web, the accuracy of models for guiding cropping decisions can be improved. We plan to integrate soil survey and remote sensing data into future versions of CropManage. The main limitation of web-based software is that users need internet access, which can be a challenge in remote areas. As cell tower coverage expands, and access and internet speed improves, these types of online tools should become increasingly useful to the agricultural community.

Literature Cited

- Cahn, M.D., and R. Smith. 2012. Improving water and nitrogen efficiency in lettuce. Proceedings of the 2012 Plant and Soil Conference, Feb. 7-8, 2012 Visalia CA. pp. 80-83.
- Gallardo, M., R.L. Snyder, K. Schulbach and L.E. Jackson. 1996. Crop growth and water use model for lettuce. J. of Irrig. and Drain. Eng. 122, No. 6: 354-359.
- Hartz, T.K., W.E. Bendixen, and L. Wierdsma. 2000. The value of pre-sidedress soil nitrate testing as a nitrogen management tool in irrigated vegetable production. HortScience 35:651-656.

Table 1. Fertilization table displayed in CropManage.

Fertilizer Date	Crop Stage/Event	Soil Nitrate Test Value	N fertilizer recommendation	Fertilizer Type	N applied	Fertilizer Applied
		ppm NO ₃ -N	lbs N/Acre		lbs/acre	gal/acre
05/06/12	1st sidedress	10	37	15-8-4	78	50
05/24/12	1st drip fertigation	20	5.1	28-0-0-5	46	15
05/29/12	2nd drip fertigation	22	11.2	28-0-0-5	31	10
06/09/12	3rd drip fertigation	26	0.0	28-0-0-5	31	10
06/11/12	4th drip fertigation	26	0.0	28-0-0-5	16	5
06/16/12	5th drip fertigation	20	56.5	AN-20	21	10
Total			110		223	

Table 2. Irrigation summary table displayed in CropManage.

Irrigation Date	Irrigation Method	Recommended Irrigation Interval	Recommend Irrigation Time	Recommended Irrigation Amount	Actual Applied Water	Crop ET
		days	hours	-----	inches -----	
04/19/12	Sprinkler	N/A	N/A	N/A	0.86	--
04/21/12	Sprinkler	1	1.1	0.33	0.53	0.25
04/23/12	Sprinkler	1	1.1	0.34	0.61	0.25
04/27/12	Sprinkler	3	0.8	0.24	0.64	0.20
04/29/12	Sprinkler	1	1.0	0.30	0.51	0.22
05/09/12	Sprinkler	5	1.2	0.37	1.44	0.31
05/24/12	Drip	7	5.3	0.79	1.17	0.72
05/29/12	Drip	7	3.0	0.45	0.76	0.41
06/03/12	Drip	5	5.1	0.77	1.07	0.69
06/09/12	Drip	4	6.4	0.96	1.10	0.98
06/15/12	Drip	4	9.2	1.39	0.76	1.25
06/19/12	Drip	4	6.3	0.94	0.79	0.84
06/23/12	Drip	4	5.5	0.82	0.92	0.74
06/26/12	Drip	4	4.2	0.63	0.52	0.57
Total			50.3	8.3	11.7	7.4

Table 3. Parameters for estimating canopy cover (eqn. 1) for various lettuce types and planting configurations.

Bed width inches	Lettuce Type	plant rows per bed	number of sites	model coefficients			
				Gmax % cover	A	B	R ²
40	Iceberg	2	7	83	6.78	-11.61	0.77
80	Iceberg	5	2	92	6.83	-12.77	0.93
80	Iceberg	6	2	89	8.23	-14.11	0.97
40	Romaine	2	2	85	3.88	-7.68	0.94
80	Romaine	5	3	86	7.07	-10.73	0.96
80	Romaine	6	7	82	7.06	-10.95	0.94

Table 4. Large plot demonstration trial comparing CropManage N fertilizer recommendation during the drip phase of the crop.

Treatment	Applied N Fertilizer ----- lbs per acre -----	Commercial Cut Product Yield
CropManage	149	18760
Grower Standard	211	19114

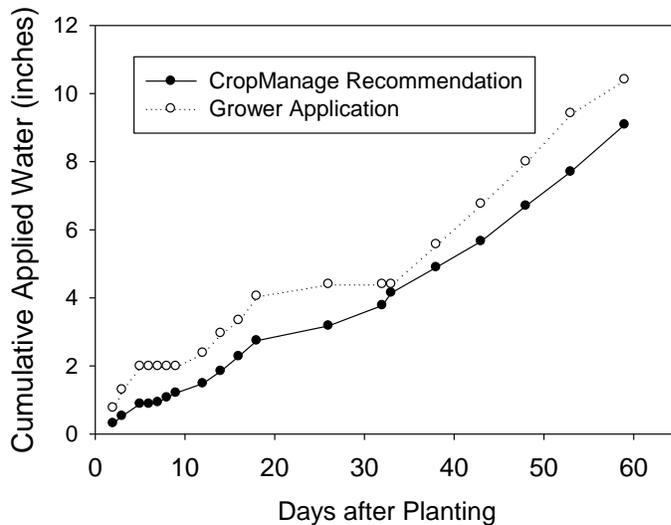


Figure 1. Comparison of actual and recommended irrigation water volumes for a commercial lettuce crop.

Designing Irrigation Systems to Manage Variable Soils

Brian Bassett, Principle Investigator, H2O Optimizer
9491 Hanford Armona Rd Hanford California 93230
Phone (559)-776-8502, bb@h2o-optimizer.com

Allan Fulton, Technical Editor, UCCE Irrigation and Water Resources Advisor
1754 Walnut Street, Red Bluff, CA 96080
Phone (530)-527-3101, aefulton@ucanr.edu

Introduction

Farm fields and irrigation systems are generally laid out in square and rectangular patterns. Similarly, irrigation and fertilizer management decisions are geared towards average or predominant field conditions but these averages ignore inherent soil variability such as meandering soils with variable water holding capacity, drainage characteristics and salinity patterns. Traditional approaches to field layout and irrigation design and management do not provide enough ability to manage this variability and it is reflected both prior to planting a crop and while growing the crop. For example, pre-plant soil samples are often composited to determine the predominant or average fertility and salinity conditions and guide field-wide management. Similarly, back hoe pit evaluations may be conducted to better understand the spatial variability of the soils in a field, but management is limited to considering the method and extent of deep tillage that is necessary to mitigate soil layers that may interfere with drainage.

In 2001 variable rate irrigation (VRI) was introduced using center pivot irrigation. The early center pivot models aimed to increase crop uniformity by controlling the speed of the center pivot to allow more water in sandy areas and less water in boggy areas with finer soil textures. The VRI system technology developed rapidly and became married to "variability maps"—maps which showed the soil variability within a field using Electromagnetic (EM) and Veris technology. These variability maps were also applied to other aspects of precision agriculture. With these developments came studies that showed water management is "the major yield determiner in nearly all agricultural settings," (Calvin Perry et al., 2001) and the suggestion that VRI has more potential to increase crop uniformity than other aspects of precision farming.

In a study published in 2002, potato yields were \$67.00 per acre higher with VRI irrigation when compared to conventional irrigation (King et al., 2002). More recently, research of site specific soil mapping methods, Electromagnetic induction (EM38) and four probe soil resistance sensors (Veris), showed that variability in almond yield correlated with variability in soil texture and water holding capacity and there may be potential to manage it with VRI. (Fulton et al., 2010).

According to the USDA, "Systems are available to producers with the ability to make variable-rate treatments (VRT) of defoliant, fertilizer, lime, pesticides, plant growth regulators, and seed. These systems could potentially offer a producer great cost savings; however, the full potential of these benefits and savings cannot be realized if water is not managed properly." (Vories et al., 2008) So, while various VRT can be very cost effective, the benefits they would have for increased crop uniformity and productivity are diminished, if the variability in plant available

water (PAW) and drainage in the effective root zone are not managed at a high level. VRI enhances, the benefits of other precision agriculture practices because it optimizes the soil-water environment in the root zone and sets the foundation for plant growth and development.

Regarding potential yield improvements from VRI, a USDA study published earlier this year says, “Every field is different as to what the potential yield improvement is possible for each crop being grown. Thus, [an] important component to consider is the recommendation to use a knowledgeable, local consultant or advisor to help analyze each particular situation.” (LaRue et al., 2012) They cite an example assessment of a field where an irrigation system was effective for all but 27% of the field, and “the roughly 27% that is under or over irrigated will probably not be able to reach its full yield potential, when using traditional approaches to irrigation design and good irrigation scheduling. A VRI system would be able to compensate for these differences.” (LaRue et al., 2012). An evaluation such as this one can be helpful for a grower who wants to estimate the basic yield improvement potential of his fields. This document is focused on experiences with Variable Rate Irrigation utilizing drip irrigation systems on two crops grown in the San Joaquin Valley of California.

Methods

General Features of Demonstration Sites.

Descriptions of two field sites are summarized below (Tables 1 and 2) where side-by-side comparisons of conventional irrigation system design and VRI have been initiated since 2010. Both vegetables and permanent crops have been included in the comparisons.

Table 1. General descriptions of two field sites where side-by-side evaluations of conventional irrigation designs and VRI are in progress.

Crop	Location	Irrigation Method	Total Acres	Area 1 (sandier soils) % of total	Area 2 (soils with more clay) % of total
Processing Tomato (Conventional)	Fresno	Buried Drip	78.8	32	68
Processing Tomato (VRI)	Fresno	Buried Drip	80.2	38	62
Pomegranates Established 2010 (Conventional)	Kings	Drip	79.6	27	73
Pomegranates Established 2010 (VRI)	Kings	Drip	80.4	39	61

Site Assessment for Suitability of VRI

Distinctly different land areas were identified in each field using EM or Veris mapping methods. Soil samples were collected at geo-referenced points at two or three locations in each area, depending on its size and used to characterize the soils in these different areas. Soils were core

sampled to a minimum sample depth of three feet. Soil horizons were sampled separately and noted by depth in inches. Samples from each area were visually inspected to confirm soil horizon depth and physical characteristics were consistent and representative of the area. These samples were then submitted to a lab for complete analysis of physical, salinity, and fertility properties. Since the primary question was whether the soil variability in each field was sufficient to warrant VRI design, water holding capacity within each area was determined. Particle size analyses using the standard hydrometer method (Gee, et.al., 1986) and USDA definitions (Rogers, 1978) of soil textural classifications and plant available water (PAW) were used in the assessment of soil variability. A minimum of three days difference in the time to reach 50 percent depletion of PAW based upon a maximum daily crop evapotranspiration rate (ET) of 0.30 inches/day was the criteria used to determine if an area was sufficiently different to irrigate separately from other areas in the field. Potential improvements in crop production and water and energy savings were also key elements of an economic analysis to assess the suitability of VRI for each field. A geo-referenced map was created for each field to identify uniquely different areas within each field and to measure the acreage of each area.

Once it was determined that a field had enough variability to warrant VRI, a statistical analysis of soil fertility and salinity was performed to determine if enough variability existed to merit site specific management of fertilizers and soil amendments. Fertilizer and amendment needs were calculated using formulas in A&L Lab’s Agronomic Handbook. Areas, accounting for more than 25 percent of the total acreage in a field, and showing economically and statistically significant differences in needs were amended and fertilized to assure that soil fertility and salinity were not limiting and that the primary management variable was PAW.

After each field was deemed “well suited” for VRI and fertilizer and soil amendments were applied to optimize these variables, these fields were split to allow side-by-side comparisons between VRI and “Conventional” irrigation designs.

Table 2. Plant Available Water (PAW) at 50 percent depletion within the primary crop root zone at each field site and within areas with different soils.

Crop	System	Area 1 50% depletion of PAW in inches	Area 2 50% depletion of PAW in inches
Tomato	VRI	2.7	3.8
Tomato	Conventional	2.8	3.8
Pomegranates	VRI	2.6	3.5
Pomegranates	Conventional	2.6	3.5

Site Specific VRI Designs

VRI systems with approximately the same acreage and proportions of sandier (light) and clay (heavy) soils were (Tables 1 and 2) installed adjacent to fields with conventional irrigation system designs. A conventional buried drip system was installed in both light and heavy areas of the tomato field and the entire field was irrigated as one set. A variable rate buried drip irrigation system was designed in the adjacent tomato field to align with the natural and irregular

patterns of soil variability identified during the initial field mapping and evaluation of the soils. A similar approach was used in the pomegranate orchard except surface drip was used instead of buried drip. For both VRI designs, one type of drip hose was installed throughout the tomato field and another single type of drip hose was installed throughout the pomegranate orchard. The same type of drip hose was used in the respective tomato field and pomegranate orchard under conventional design. Using one type of drip hose across the VRI system simplified future maintenance and repairs. However, in the VRI irrigated fields, the buried drip and above ground drip systems were installed within defined geo-referenced areas of each field matching the natural soil variability and the irrigation of these areas were controlled by separate, manually controlled or automatic valves. In some cases, where the irrigated acreage within different areas of the VRI system were significantly different, variable frequency drives were necessary to vary the flow rate and control the pressure into each irregularly shaped irrigation set.

Management of VRI and Conventional Irrigation Systems

Applied water was measured with flow meters for each separately controlled area of the VRI systems and in the conventional systems. Soil moisture capacitance sensors were installed in each field. The sensors were installed in representative areas of the conventional irrigation system and within each irrigation set of the VRI systems. Volumetric soil moisture content was monitored daily and measured every 3.9 inches to a depth of 39.5 inches. Summed graphs of volumetric soil moisture (Figures 1 & 2) were generated from daily, incremental soil moisture measurements and utilized to determine weekly schedules of irrigation frequency and duration. Irrigation was managed to try to avoid extremes in soil moisture levels. The objective was to maintain soil moisture content in the root zone below field capacity and greater than 50 percent depletion of plant available water (PAW) until harvest approached. The overall goal was to provide a desirable combination of adequate moisture and aeration and presumably improved nutrient uptake, and active root and crop development.

Results

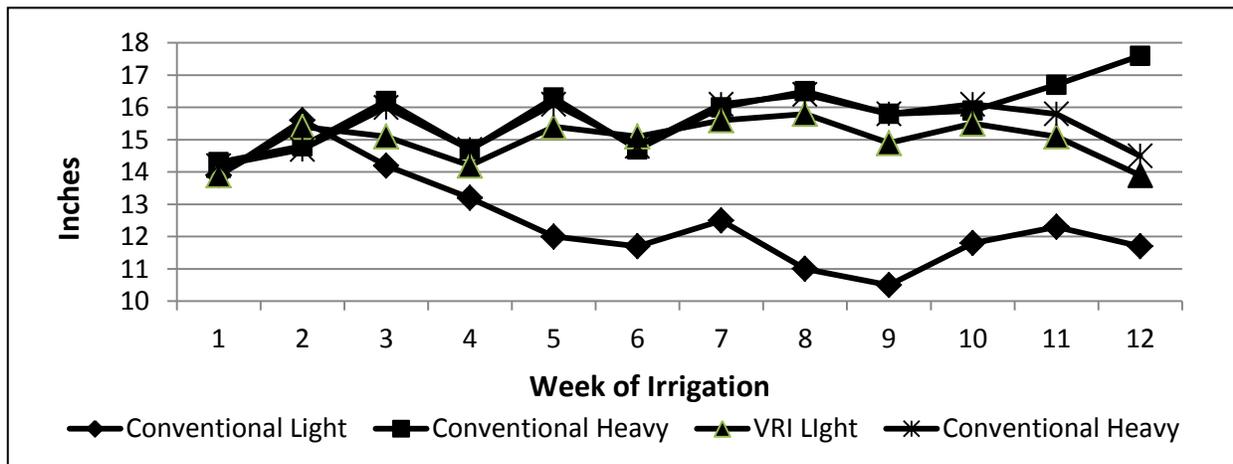
Soil Moisture Levels and Irrigation Schedules in Tomato

A range in soil moisture content of 10.5 to 15.2 inches was maintained throughout the entire season in the areas of the field with light textured soils with conventional buried drip design (Figure 1). In comparison, soil moisture content ranged from 13.9 and 15.8 inches in areas with light textured soils irrigated with VRI design. With VRI, PAW was steadily maintained above 50 percent depletion for the duration of the season in the areas of the tomato field with light soil textures until it was appropriate to cut back irrigation at fruit maturity. In contrast, under conventional irrigation, the soil moisture was highest on week 2 of the growing season and steadily declined beyond 50 percent depletion of PAW through week 9. An increase in soil moisture occurred during week 7 and appeared to be associated with lower ET rates because the irrigation frequency (Table 1) of the conventionally designed system in the area of light soils remained constant at two times per week and the duration was decreased from 24 to 18-hour sets. With this irrigation schedule in the light textured areas under conventional design, incremental soil moisture sensors indicated that more water was applied than the soil could hold and it appeared to drain below the primary root zone. The frequency between irrigations also

appeared too many days apart to maintain optimum soil moisture. In response, as the fruit began to size, the tomato canopy declined in vigor as the soil moisture continued to decrease. Substantial plant desiccation was observed in the lightest textured areas of soil. Beginning in week 9 (Table 1), the irrigation frequency was increased from 2 times per week to 3 times in an effort to address the declining canopy in the areas of lighter soil. The duration of irrigation was also reduced in 6 hour increments from 18 to 6 hours per week during weeks 9 through 12.

While the irrigation scheduling in the light textured areas under conventional irrigation design were being managed to overcome the challenge of excessively dry soils and declining tomato canopy, total soil moisture content ranged from 14.0 to 17.6 inches in the areas of the field with heavy textured soils (Figure 1). The soil moisture levels in this area were generally more consistent under conventional irrigation design from week 2 through 10 than was observed in the areas of lighter soil. There were no concerns with canopy desiccation during fruit sizing in this area. However, from week 10 through 12 the soil moisture continued to increase when ideally it should have begun to decline to encourage fruit coloring and accumulation of solids and aid in drying the soils in preparation for harvest. This increase in soil moisture was the result of the more frequent irrigation scheduling during week 10 through week 12 in the lighter textured soils within the same irrigation set.

Figure 1. Total soil moisture content to 39.5 inches in light (sandier) and heavier (clay) textured areas of tomato field irrigated with conventional and VRI buried drip designs.



With the VRI design and the ability to irrigate the light and heavy soils differently, soil moisture levels were remarkably similar. Soil moisture levels ranged from 13.7 to 14.4 inches from week 1 through week 10 in the light textured soils and 13.9 to 16.1 inches in the heavy textured soils. Soil moisture was consistently above 50 percent depletion of PAW in both areas of light and heavy soil texture. The distinct separation in soil moisture content between areas of different soil texture and water holding capacity was not apparent with the VRI design as was the case with the conventional design. In addition, soil moisture levels declined appropriately in both areas of light and heavy soils during week 10 through 12 when irrigation was cutback and eventually cutoff. In response, the uniformity of tomato canopy was improved, concerns over plant

desiccation in areas with light textured soils was prevented, and soil moisture depletion decreased appropriately to enhance crop maturation and prepare for harvest.

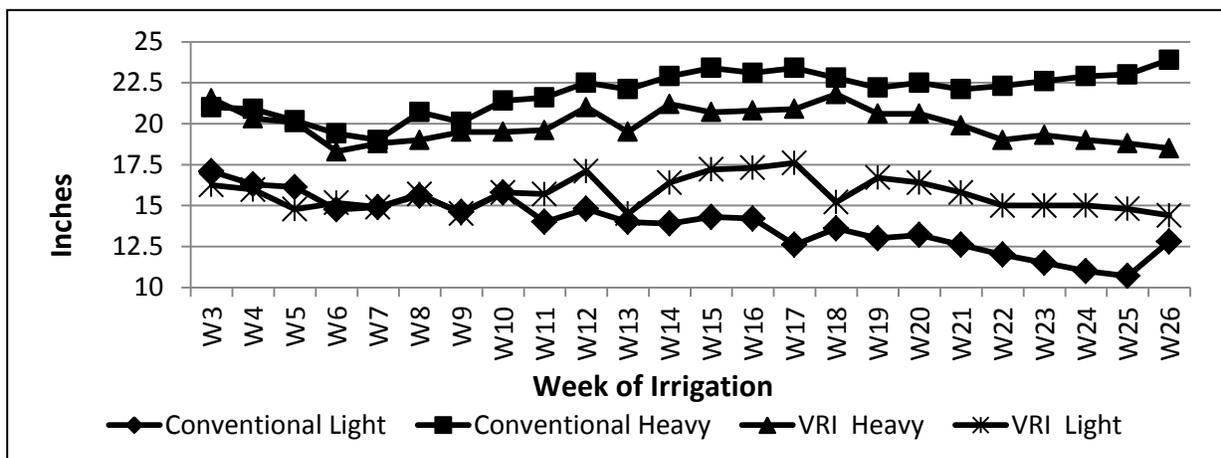
Table 3. The number of irrigations each week (frequency) and the hours of irrigation (duration) in tomato field. Highlighted cells indicate frequency and duration are significantly different in VRI.

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Conv. Light	2 x 12	2 x 18	2 x 24	2 x 24	2 x 24	2 x 24	2 x 18	2 x 18	3 x 18	3 x 12	3 x 6	2 x 6
Conv. Heavy	2 x 12	2 x 18	2 x 24	2 x 24	2 x 24	2 x 24	2 x 18	2 x 18	3 x 18	3 x 12	3 x 6	2 x 6
VRI Light	2 x 12	3 x 12	4 x 12	4 x 12	4 x 12	4 x 12	3 x 12	2 x 12	2 x 12	3 x 6	3 x 6	2 x 6
VRI Heavy	2 x 12	2 x 18	2 x 24	2 x 24	2 x 24	2 x 24	2 x 12	2 x 12	2 x 6	2 x 6	1 x 6	N/A

Soil Moisture Levels and Irrigation Schedules in Pomegranates

A range in soil moisture content of 9.7 to 16.7 inches was observed throughout the entire season in the areas of the orchard with light textured soils under conventional drip design (Figure 2). In comparison, soil moisture content ranged from 13.6 to 15.6 inches in areas with light textured soils irrigated with VRI drip design. With VRI, PAW was steadily maintained above 50 percent depletion for the duration of the season in the areas of the pomegranate orchard with light textured soils. In contrast, under conventional design, the soil moisture was highest on week 1 at 16.7 inches and steadily declined to 9.7 inches on week 25 of the growing season. Beginning on week 13 soil moisture content was at about 50 percent depletion of PAW or drier for the remainder of the season and posed problems with inadequate tree vigor and yield potential.

Figure 2. Total soil moisture content in light (sandier) and heavier (clay) textured areas of a Pomegranate orchard with conventional and VRI drip designs.



Conversely, soil moisture content ranged from 18.5 to 23.5 inches in the area of the orchard with heavier textured soils and the trend of soil moisture content progressively increased from week 1

through week 26. Beginning week 14 through week 26, periods occurred where soil moisture levels were excessively wet and caused concern for long term tree health and harvestable fruit quality. This trend of increasingly higher soil moisture content was opposite of the progressively drying trend in the area of the orchard with lighter textured soils. These opposing trends demonstrated the difficulty of optimizing soil moisture conditions in the crop root zone under conventional irrigation design that did not match well with the natural soil variability. Table 4 shows that beginning on week 17 and continuing through week 26, an optimum combination of increased irrigation frequency and reduced irrigation duration was not found to balance the different areas with lower and higher water holding capacity with the conventional design.

Table 4. The number of irrigations each week (frequency) and the hours of irrigation (duration) in pomegranate orchard. Highlighted cells indicate frequency and duration are significantly different in VRI.

	Conventional Heavy	Conventional Light	VRI Heavy	VRI Light
W3	1 x 6	1 x 6	1 x 12	1 x 6
W4	1 x 8	1 x 8	1 x 12	1 x 8
W5	1 x 10	1 x 10	1 x 12	2 x 5
W6	1 x 12	1 x 12	1 x 12	2 x 6
W7	1 x 18	1 x 18	1 x 12	2 x 6
W8	1 x 24	1 x 24	1 x 24	2 x 12
W9	1 x 24	1 x 24	1 x 24	2 x 12
W10	1 x 24	1 x 24	1 x 24	2 x 12
W11	1 x 24	1 x 24	1 x 24	2 x 12
W12	1 x 24	1 x 24	1 x 24	2 x 12
W13	1 x 24	1 x 24	1 x 24	2 x 12
W14	1 x 24	1 x 24	1 x 24	2 x 12
W15	1 x 24	1 x 24	1 x 24	2 x 12
W16	1 x 24	1 x 24	1 x 24	2 x 12
W17	2 x 12	2 x 12	1 x 24	2 x 12
W18	2 x 12	2 x 12	1 x 24	2 x 12
W19	2 x 12	2 x 12	1 x 12	1 x 12
W20	2 x 12	2 x 12	1 x 10	1 x 10
W21	1 x 12	1 x 12	1 x 6	2 x 4
W22	1 x 12	1 x 12	1 x 6	2 x 4
W23	1 x 12	1 x 12	1 x 6	2 x 4
W24	1 x 12	1 x 12	1 x 4	2 x 4
W25	1 x 12	1 x 12	1 x 2	2 x 4
W26	1 x 12	1 x 12	N/A	2 x 4

When VRI drip design was employed in the pomegranate orchard, soil moisture content in the area of the orchard with lighter textured soils ranged from 13.7 to about 17.2 inches in the root zone (Figure 2). Soil moisture levels in the light textured areas were much more consistent during the growing season than levels attained with the conventional irrigation design with similar lighter textured soils and seldom fell below 50 percent depletion. With VRI, the area of the orchard with heavier textured soils ranged from about 17.7 to 21.4 inches. Soil moisture

levels were sustained below field capacity and generally above 50 percent depletion of PAW and sufficiently addressed concerns about crop response under conditions of high stress from under-irrigation and tree health and fruit quality from over-irrigation. The VRI drip design enabled much more flexibility and control when making irrigation scheduling decisions about irrigation frequency and duration (Table 4).

Tomato and Pomegranate Responses

VRI designed systems produced more uniform crops across areas with distinctly different soils compared to conventional designed systems in both tomatoes and pomegranates. Applied water was reduced on average by 1.1 and 1.4 acre feet per acre in tomatoes and pomegranates, respectively, with VRI designs. Tomato yields in areas with heavy soil textures were increased on average by 18.7% and yields in lighter textured soils were 75.1% higher. Pomegranate quality was significantly improved in heavy areas, averaging 60.2% more fresh market fruit with VRI systems. Little difference in pomegranate quality was noted in lighter textured areas between conventional and VRI drip designs.

Added Costs of VRI Designs

VRI system costs were increased over conventional designs due to the soil mapping and additional drip system parts and installation costs. The VRI drip used to irrigate pomegranates required additional PVC pipe and control valves. This increased the cost of system design and installation by 19.3% or \$180.00 per acre. The VRI buried drip system in tomatoes required additional lay-flat pipe and additional control valves that increased system design and installation costs by 14.7% or \$130.00 per acre.

Conclusions

VRI buried drip and surface drip systems provided added management control and flexibility to vary the frequency and duration of applied irrigation water based on crop needs. These needs were predicated by stage of growth, weather (ET), and soil moisture content. During the vegetative growth phases of tomatoes and pomegranates, VRI designs enabled higher frequency and shorter duration irrigations to be applied to the areas of light textured soils with lower water capacity. While less frequent irrigations of longer duration and earlier irrigation cutback and cutoff were possible with VRI designed systems in areas of heavier textured soils with higher water holding capacity. Because VRI afforded improved control and flexibility of irrigation management, improved crop health and productivity was also achieved. VRI system costs were increased on average by 17 percent. Water savings averaged 1.25 acre feet per acre in these field experiments. The Return on investment is two to three years depending on specific water costs and crop responses. VRI irrigation system design has potential benefit for a variety of pressurized irrigation methods and a variety of annual and permanent crops. Further investigations and efforts are warranted to encourage wider familiarity and adoption of VRI design concepts.

Literature Cited

A&L Labs Soil and Plant Analysis, Agronomy Handbook 2001 Edition

http://www.allabs.com/publications/agronomy_handbook2.aspx Pg. 15,25,41-46, 50, 54, 60-61, 64, 68, 73, 76, 97-99.

Fulton A., Schwankl L., Lynn, K., Lampinen, B., Edstrom, J., Prichard, T. 2010. Journal of Irrigation Science. Using EM and Veris technology to assess land suitability for orchard and vineyard development. Irri. Sci. DOI 10.1007/s00271-010-0253-1 Pg. 1.

Gee GW, Bauder JW (1986) Particle size analysis. In: Klute A (ed) Methods of soil analysis. Part 1. Physical and mineralogical methods. Agron. Monogr. 9, 2nd edn. ASA and SSSA, Madison, WI, pp 383–411.

King A.B., Reeder, E. R., Wall, W. R., Stark, J.C., 2002 ASAE Annual International Meeting. Comparison of Site Specific and Conventional Irrigation Management for Potatoes. Pg. 02-2175.

LaRue, J. , Evans R., February 2012 Proceedings of the 24th annual Central Plains Irrigation Conference. Colby Kansas February 21-22, 2012. Considerations for Variable Rate Irrigation. Pg.111-115.

Perry, C., Pocknee, S., 2003. Proceedings of the Georgia Water Resources Conference held April 23-24, 2003 at the University of Georgia. Development of a Variable Rate Pivot Irrigation Control System. Pg. 3-5.

Rogers, J.H. 1978. Aids for estimating Soil Properties for USDA-SCS—Soils—5 Forms in California, USDA, SCS, Davis, Ca. Pg. 6.

Vories, E., 2008. 14th Annual Judd Hill Cotton Technology Field Day. Variable Rate Irrigation for Humid Climates Pg. 1-2.

Water Management Strategies for Table Grapes

Isabel Abrisqueta, USDA-ARS, Water management Research Laboratory,
9611 S. Riverbend Avenue, Parlier, CA 93648
Phone (559) 596-2896, isabel.abrisqueta@ars.usda.gov

James E. Ayars, USDA-ARS, Water management Research Laboratory,
9611 S. Riverbend Avenue, Parlier, CA 93648
Phone (559) 596-2875, james.ayars@ars.usda.gov

Introduction

Water scarcity, impaired water quality, decreased soil quality, and aberrant weather are listed among the top risks to grape production in the western U.S (Thrupp *et al.*, 2008). Grapes are the highest value fruit crop produced in the U.S, and all grape products combine to generate an estimated \$162 billion impact on the American economy each year. Perhaps the most important issue associated with global warming for California is related to water availability (Weare, 2009). California's warmer winters and springs have led to reduced snow-pack, increasing the seasonality of water flows and directly affecting the ability to grow plants, produce food and support growing populations (Allen-Diaz, 2009).

A multi-state, multi-institution cooperative project “*Developing sustainable vineyard water management strategies for limited and impaired water supplies*” was funded by the NIFA Specialty Crops Research Initiative to determine sustainable water management practices for wine, table, juice and raisin grape production. The first objective of the project is to determine the effects and limits of deficit irrigation strategies on vine development, yield and grape quality for table, wine, juice and raisin production. This report covers the first two year's data for deficit irrigation of table grape production in the San Joaquin and Coachella Valleys.

Materials and Methods

Starting in 2011, two 2.22 acre plots areas were established in commercial table grape vineyards to implement the water stress strategies. One is located in the Coachella Valley (Mecca, California) on a ‘Sugraone’ (own root), early maturing table grape with a prolonged postharvest period and potential for significant water savings. The ‘Sugraone’ variety is an early-season white seedless grape with large berries and a slight Muscat flavor when fully ripe.

The other plot, is on a ‘Crimson Seedless’ late maturing table grape (Delano, California) with a small postharvest period available for water savings. ‘Crimson Seedless’ is a late season table grape that ripens in early October and, weather permitting, can be held on the vine through mid-November. When properly mature, the fruit of ‘Crimson Seedless’ is bright red and has excellent eating characteristics; its berries are firm and crisp and have good flavor. Plus, late fruit maturation extends the market availability of seedless table grapes into the late fall (Dokoozlian *et al.* 1995).

In both sites, rows (west-east oriented) contain 32 vines spaced 7 feet apart within the row and 12 feet between rows. The plots contained 3 rows with the middle row being the data row. The vines are drip irrigated with one lateral on each vine row with three emitters per vine and a discharge of 1 gal/hr. In the Delano vineyard the drip line was placed on the ground while in Coachella Valley, the drip line was attached to a wire on the row line at 12 inches above the

ground. Overhead V trellis system is the training used in ‘Sugraone’ vineyard while in Delano is a Y trellis system.

There were 3 treatments and 4 replications in a randomized complete block design. Irrigation treatments were: T1 as the normal Grower Practice (GP) and two deficit irrigated treatments, T2 and T3, as a percentage reduction of GP (Table 1). In the first year we established the normal grower practice, and modified the grower practice based on percentage reduction during specific growth stages instead of developing strategies based on a determination of crop evapotranspiration.

Table 1. Description of table grape irrigation treatments in both places, ‘Sugraone’ in Mecca and ‘Crimson Seedless’ in Delano, during 2011 and 2012. Treatments are expressed as a percentage reduction of the normal grower practice (GP). General phenological stages are indicated.

Sugraone	P. Stage	Bud Break	Bloom			Berry softening	Harvest			Postharvest			Dormancy & Pruning	
	Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2011	GP	Grower Practice (GP)											No irrigation	
	T2	90% of GP					87%							
	T3	80% of GP					76% of GP							
2012	GP	Grower Practice (GP)											No irrigation	
	T2	75% of GP												
	T3	50% of GP			75% of GP			50% of GP						
Crimson Seedless	P. Stage	Dormancy & Pruning		Bud Break	Bloom		Fruit Set	B. format.	Postveraison		Harvest			
	Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2011	GP	Grower Practice (GP)												
	T2	No irrigation	80% of GP					82% of GP						
	T3		80% of GP					65% of GP						
2012	GP	Grower Practice (GP)												
	T2	No irrigation	80% of GP				100% of GP		80% of GP					
	T3		60% of GP				100% of GP		70%	60% of GP				

GP= Grower practice; P. Stage= Phenological stage; B. Format= Berry formation.

Soil and plant water status were measured weekly as well as shaded area of the vines. Trunk diameter was measured at the beginning and end of the season. At the end of the season, the pruning was performed in December for ‘Sugraone’ and January for ‘Crimson Seedless’. The total amount of pruned wood per vine was measured.

Yield was determined at harvest, June for ‘Sugraone’ and November (with 4 picks) for ‘Crimson Seedless’, based on the weight of the total and commercial packed fruit per vine. At harvest, 100 berries were taken in each replication for fruit quality; berry weight, diameter, firmness (FirmTech, BioWorks, Inc., Wamego, KS, USA), color with a reflectance colorimeter (Konica Minolta CR400), pH and titratable acidity. Also, a commercial box of fruit was stored at 0.5^o C for a postharvest evaluation (three weeks later). This evaluation consisted in final box weight, decayed berries from 10 clusters, number of brown berries, index of rachis condition (0=fresh, 5=completely brown) and in ‘Crimson Seedless’, the number of berries with soft tip was also counted.

Results and Discussion

‘Sugraone’

From May 2010 to May 2011 the total water applied for the GP, T2 and T3 treatments was approximately 49, 47 and 45 inches respectively, which means that treatment T2 was irrigated at 95% and T3 at 91% of GP. For the next season, 2011-2012, these depths were 52, 42

and 37 inches in GP, T2 and T3 respectively, which means an irrigation of 82% in T2 and 72% in T3 with respect to the normal grower practice (Table 2).

Table 2. Irrigation volumes applied for each treatment in inches per vine and percentages of irrigation with respect to the normal grower practice irrigation (GP), during the production seasons 2010-2011 and 2011-2012 in ‘Sugraone’ experimental vineyard. Production season is considered from harvest of one year to harvest of next year. Reference evapotranspiration (ET_o) in inches.

	2010			2011			2012			2010-2011		2011-2012	
	Post	Pre	%	Post	%	Pre	%	Post	%	Total	%	Total	%
GP	29	20	100	29	100	22	100	17	100	49	100	52	100
T2	29	17	88	25	87	17	75	16	91	47	95	42	82
T3	29	15	77	22	76	15	68	13	76	45	91	37	72
ET _o	42	29		46		29		41		71		75	

During the first season harvest, 2011, no significant differences were found at harvest in total yield between treatments (Figure 1 A), even with reductions in the irrigation volume of 12% and 23% in T2 and T3 respectively were performed during the pre-harvest (Table 2).

On the other hand, in the 2012 harvest (Figure 1 B), the GP and T3 obtained similar total yields, and T2 was significantly different, with the largest commercial packed weight and the smallest value for lost weight, even with almost 20% less water applied during the whole season compared to the normal grower practice (Table 2). The reduce irrigation consisted of 13% less during postharvest in 2011 and 25% less during pre-harvest in 2012.

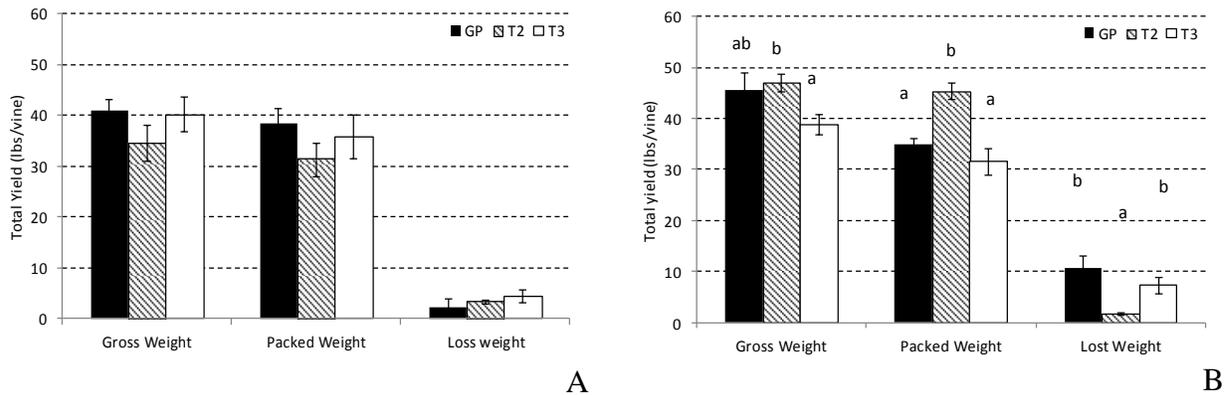


Figure 1. Final yield (lbs. per vine) obtained in each treatment during 2011 (A) and 2012 (B). Gross weight corresponds to the amount of fruit without cleaning, packed weight is the commercial packed weight and lost weight is the part of the fruit lost in the process of cleaning. Black solid fill is the grower practice treatment (GP), pattern fill is T2 and white solid fill is the T3. Vertical bars correspond to standard error. Different letters means significant differences according to Tukey’s test ($p \leq 0.05$).

Irrigation in T3, with almost 30% less water than the GP during the whole season went through a specific reduction of 24% at postharvest 2011 and 32% at preharvest 2012. This did not seem to result in a positive effect as in T2. However, it had a yield similar to the GP.

In terms of fruit quality, in the 2011-harvest, T2 and T3, with a reduction of more than 10% and 20% in irrigation, compared to the grower practice during preharvest, accelerated berry maturity, especially in T2. Positive differences were found in the higher soluble solids and low acid content (Table 3). These significant differences were achieved again for T2 at 2012-harvest with 20% less water but T3, on the other hand, with a reduction of almost 30%, did not show any

significant differences compared to the GP in soluble solids or acid content. T3 berries were softer as a result of water stress but were not as sweet as T2 or GP.

Table 3. External and internal quality test results in ‘Sugraone’ table grape at harvest (June) in 2011 and 2012. Each value is the average of 400 berries.

Year	Treatment	External physical quality				Internal chemical quality						
		Diameter	Firmness	Berry wt		Soluble solids	Potassium	pH	TA			
2011	GP	22.4	b	464	6.1		16.2	a	978	3.58	5.41	
	T2	22.3	b	471	6.1		17.5	b	955	3.61	4.57	
	T3	22.0	a	457	5.9		16.9	ab	954	3.54	4.92	
	Sig.	0.000		0.067	0.056		0.000		0.348	0.073	0.052	
2012	GP	22.3	a	375	b	6.1	14.3	ab	984	3.73	4.20	ab
	T2	22.4	ab	359	a	6.0	14.8	b	1006	3.73	3.87	a
	T3	22.7	b	359	a	6.0	14.0	a	1032	3.75	4.46	b
	Sig.	0.014		0.001	0.685		0.011		0.232	0.439	0.007	

Diameter= berry diameter in millimeters; Firmness= grams to cause a 1 mm deflection; Berry wt: weight in grams; Soluble solids (^oBrix) of the juice; Potassium content in parts per million; pH of the juice; Titratable acid content, grams tartaric acid/L of juice. Values followed by unlike letters are significantly different by Tukey’s HDS ($p \leq 0.05$)

The yield efficiency (YE), lbs. of fruit per trunk cross section area, and water use efficiency (WUE), lbs. of fruit per inch of water applied, are terms that relate the size of the vine or applied water with the final production of the vine (Table 4). In 2011 no differences were found between treatments in either of these terms, probably because no enough deficit were performed during the season 2010-2011.

At harvest 2012, T2 achieved the highest YE and WUE with significant differences giving the largest production and the lowest fruit loss rate (Table 4). T3, showed WUE values between GP and T2, having production similar to grower practice but with 30% less applied water.

In terms of water use efficiency, deficit treatments were more effective than the normal grower practice, improving, in the case of T2, quality parameters as the sugar content, that are demanded by the consumer.

Table 4. Total gross and commercial packed yield at harvest with the percent of fruit lost for each treatment during 2011 and 2012 at ‘Sugraone’ vineyard. Trunk cross section area (TSA) in square inches is the average of 50 trunk vines per treatment. Yield efficiency as the rate between lbs. of fruit per trunk section area and Water Use Efficiency (WUE) as a result of the rate between lbs. of fruit per inch of water applied in each treatment and year.

Year	Treatment	Harvest (lbs./vine)				TSA	Yield Efficiency	WUE					
		Gross	Packed	% Loss rate		sq. inch	lbs./sq. inch	lbs./inch					
2011	GP	40.8	38.4	5.8		8.5	4.7	0.83					
	T2	34.4	31.3	9.2		7.3	4.8	0.74					
	T3	40.1	35.7	11.0		8.3	5.0	0.90					
	Sig.	0.128	0.145	0.413		0.071	0.845	0.126					
2012	GP	45.6	ab	34.8	a	23.6	c	8.8	ab	5.5	ab	0.88	a
	T2	47.0	b	45.3	b	3.6	a	7.8	a	6.0	b	1.09	b
	T3	38.8	a	31.6	a	18.6	b	9.0	b	4.4	a	1.04	ab
	Sig.	0.045		0.000		0.000		0.047		0.004		0.023	

Values followed by unlike letters are significantly different by Tukey’s HDS ($p \leq 0.05$)

The postharvest evaluation (3 weeks later) corroborated the acceleration in maturity achieved in the deficit treatments with highest values in skin browning, especially in T2 both years (data not shown).

‘Crimson Seedless’

Considering the season, from veraison to harvest in 2011 (August to November), irrigation in T2 corresponded the 80% of the GP while in T3 it was the 65% (Table 5). During the particular veraison stage (August), T2 was irrigated at 70% GP and T3 just the 40% (data not shown). Irrigation in November was performed at the same level in all treatments for frost protection purposes.

During the next year, 2012, from dormancy to veraison T2 and T3 were irrigated at 84% and 82%, maximum, from GP respectively. From veraison to harvest period, T2 continued being irrigated at 80% and T3 were irrigated at 65% (Table 5).

Table 5. Irrigation volumes applied for each treatment in inches per vine and percentages of irrigation respect the normal grower practice irrigation (GP), during the production seasons 2011 and 2012 in ‘Crimson Seedless’ experimental vineyard. Production season is considered from January to October. Each season is divided by most important phenological stages: Dormancy (Dorm.), Veraison (Ver.) and harvest. Rainfall (R) and Reference evapotranspiration (ETo) in inches are also indicated. Data is completed until November, 2012.

	2011				2012				Total		Total	
	Dorm. to Ver.		Ver. to harvest		Dorm. to Ver.		Ver. to harvest		2011		2012	
	Jan to Jul	%	Jul to Oct	%	Jan to Jul	%	Jul to Oct	%	%	%	%	
GP	29	100	11	100	29	100	7	100	40	100	36	100
T2	29	100	9	82	25	84	6	82	38	95	30	84
T3	28	99	7	65	24	82	4	63	35	89	28	78
R	5		0		4		0		5		4	
ETo	31		18		36		17		48		52	

Larger reductions in irrigation volumes were achieved during 2012 than 2011 due to the late start of the deficit treatments in August 2011. The reductions during August 2011 (30% and 60% less water for T2 and T3 respectively) did not cause significant differences at harvest for the total yield but modified some quality parameters in berries from T3.

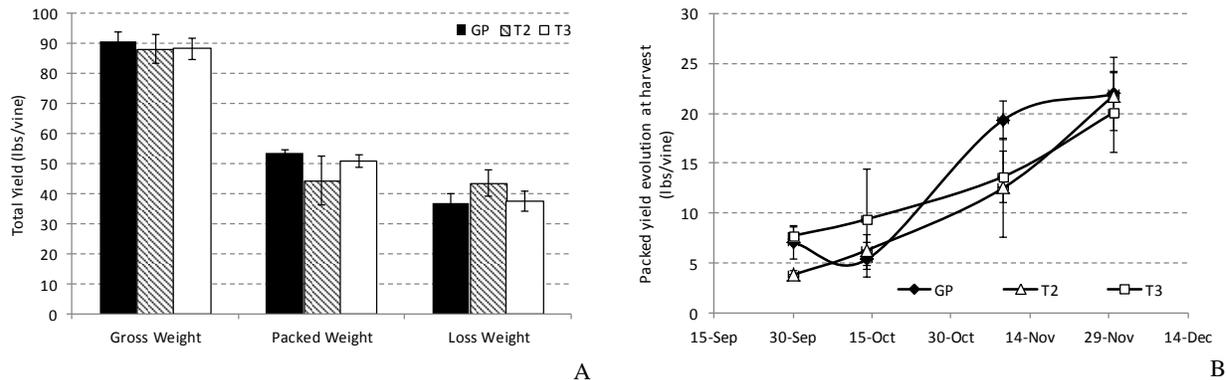


Figure 2 . A) Final yield (lbs. per vine) obtained from each treatment at 2011 harvest. Gross weight corresponds to the amount of fruit without cleaning, packed weight is the commercial packed weight and lost weight is the part of the fruit lost in the process of cleaning. Verticals bars correspond to standard error; B) Total commercial packed yield per vine along the harvest period

Harvest in 2011 lasted two months, October and November, with a total of four picks. The fifth pick scheduled for December was processed as raisins due to frost damage. Even though no significant yield differences were found between treatments (Figure 2A) according to Tukey’s test ($p \leq 0.05$), T3 shows a slightly greater increment of yield early in the period compared to the others treatments (Figure 2 B). Water deficit (reduction of 60% GP) during August could have

accelerated fruit maturation. Similar behavior is observed in the current year, 2012, but the harvest is was not complete at the time of preparation of this manuscript.

Irrigation strategies did not cause significant differences between treatments in the external quality parameters (Table 6). In terms of internal quality, no significant differences between treatments were found for pH and Titratable acid parameters. However, T1 showed the highest value for potassium content while, T3 did for soluble solids. T2 had the lowest values for both parameters (Table 6). The high content of soluble solids in T3 can be explained by the 60% of reduction in irrigation at veraison. El-Ansary *et al.* (2005) obtained similar results in table grapes cv. ‘Muscat of Alexandria’ where severe RDI decreased firmness and acidity and increased total soluble solids of the berries.

Table 6. External and internal quality test results in ‘Crimson Seedless’ table grape at harvest (October and November) in 2011. Each value is the average of 400 berries.

Year	Treatment	External physical quality			Internal chemical quality					
		Diameter	Firmness	Berry wt	Soluble solids	Potassium	pH	TA		
2011	GP	20.4	363	5.7	18.5	ab	1079	b	3.55	4.45
	T2	20.3	362	5.6	18.3	a	1014	a	3.82	4.15
	T3	20.3	361	5.7	18.6	b	1040	ab	3.76	3.55
	Sig.	0.057	0.892		0.026		0.035		0.598	0.324

Diameter= berry diameter in millimeters; Firmness= grams to cause a 1 mm deflection; Berry wt: weight in grams; Soluble solids (^oBrix) of the juice; Potassium content in parts per million; pH of the juice; Titratable acid content, grams tartaric acid/L of juice. Values followed by unlike letters are significantly different by Tukey’s HDS (p≤0.05)

Berries from T2 showed more lightness (L*) and less red color (h^o) than the other treatments (Table 7). A sustained deficit could delay the color maturity while, in T3, with values near to T1 (Table 7), the 60% ‘shock’ deficit during veraison, could accelerate the color development of the berries. According to the field crew, a general delay of color development happened in the area during 2011 season. That’s a common problem with this table grape variety, Dokoozlian *et al.* (1995) indicated that 30% or more of the fruit produced by this cultivar may remain on the vine due to inadequate color development.

Table 7. Berry color analysis (CIELAB color system, 1986) of table grape ‘Crimson Seedless’ at 2011 harvest. Each value is the average of the four picks events.

	L*		C*		h ^o	
GP	29.8	a	12.4	b	28.5	a
T2	30.3	b	12.0	a	29.9	b
T3	29.9	a	12.2	a	28.9	ab
Sig.	0.000		0.000		0.003	

L*= lightness; V*= chroma; h= hue angle; Values followed by unlike letters are significantly different by Tukey’s HDS (p≤0.05)

Postharvest evaluation (three weeks later) did not show significant differences between treatments for any parameter studied soft tip, gray mold, rots, shatter berry and rachis rating (data not shown).

Even when deficit treatments and grower practice treatment did not show significant differences in terms of Yield efficiency and Water use efficiency at harvest 2011 (Table 8), T3 showed the highest value for WUE. It will be interesting to analyze during the current season, if the largest reductions applied during 2012, would achieve significant efficiencies at deficit treatments.

Table 8. Total gross and commercial packed yield at harvest with the percent of fruit lost for each treatment during 2011 at ‘Crimson Seedless’ vineyard. Trunk cross section area (TSA) in square inches is the average of 50 trunk vines per treatment. Yield efficiency as the rate between lbs. of fruit per trunk section area and Water Use Efficiency (WUE) as a result of the rate between lbs. of fruit per inch of water applied in each treatment and year.

Year	Treatment	Harvest (lbs./vine)			TSA	Yield Efficiency	WUE
		Gross	Packed	% Loss rate	sq. inch	lbs./sq. inch	lbs./inch
2011	GP	90.7	53.8	40.6	23.3	3.9	2.27
	T2	88.2	44.5	50.3	22.7	4.0	2.32
	T3	88.5	50.9	42.3	24.3	3.7	2.49
	Sig.	0.891	0.407	0.457	0.567	0.764	0.363

Summary

The application of deficit strategies with respect the normal grower irrigation practice resulted in reduced irrigation at both sites. The ‘Sugraone’ treatments T2 and T3 were irrigated in 2011 at 5% and 10% less than the grower practice and, almost 20% and 30% less in 2012. For ‘Crimson Seedless’, this reduction was 5% and 10% for T2 and T3 in 2011 and 16% and 22% in 2012. Specific reductions at veraison were also performed both years for “Crimson Seedless”.

The 2011 harvest data for yield, both the ‘Sugraone’ and ‘Crimson Seedless’ deficit treatments did not show significant differences with the grower practice treatment (GP).

The 2012 harvest data for ‘Sugraone’ demonstrated positive effects in T2, with significant differences, with the largest commercial packed weight, yield efficiency, water use efficiency and less fruit lost in the cleaning process, while T3 and GP had similar values in all those parameters even with almost 30% of difference in irrigation water between T3 and the GP.

Positive effects were found for deficit treatments in terms of fruit quality, achieving highest values for soluble solids in ‘Sugraone’ T2, both years, and ‘Crimson Seedless’ T3 in 2011. On the other hand, the reduction of irrigation water of almost 30% in ‘Sugraone’ T3 during 2012, had the negative result of berries that were softer than GP but not as sweet as T2.

Reductions of 10% at post-harvest and 25% at pre-harvest seems to be appropriate to achieve a larger yield and highest sugar content in berries for an early maturing table grape in the Coachella Valley, but needs to be replicated at least one more year.

Berries from ‘Crimson Seedless’ T3 in 2011, had more soluble solids compared to the other treatments and a color development near to the berries from grower practice treatment and the firmness was not affected.

After the first two harvests of ‘Crimson Seedless’ we noticed a slightly greater increment of yield early in the harvest period for T3 compared to the other treatments, although it was not statistically significant. This may be a response to the reduction in irrigation water during veraison.

References

- Allen-Diaz, B.H. Editorial: Climate change affects us all. *California Agriculture* 63 (2): 51-53. DOI: 10.3733/ca.v063n02p51. April-June 2009.
- Weare, B.C., How will changes in global climate influence California? *California Agriculture* 63(2):59-66. DOI: 10.3733/ca.v063n02p59. April-June 2009.
- Thrupp L.A., Browde J., Francioni L., Jordan A. (eds.). 2008. Reducing risks through sustainable winegrowing: a grower’s guide. California Sustainable Winegrowing Alliance.
- Dokoozlian, N., Luvisi, D., Moriyama, M., Schrader, P. Cultural practices improve color, size of ‘Crimson Seedless’. *California Agriculture* 49(2):36-40. DOI: 10.3733/ca.v049n02p36. March-April 1995

El-Ansary, D.O., Nakayama, S., Hirano, K. & Okamoto, G., 2005. Response of Muscat Alexandria table grapes to post-veraison regulated deficit irrigation in Japan. *Vitis* 44, 5-9.
CIELAB color system, Commission Internationale de l'Eclairage. (1986). Colorimetry. Publication CIE no 15.2, Vienna

Acknowledgement

This research was funded through the National Institute of Food and Agriculture's Specialty Crops Research Initiative. We thank the table grape collaborators for their support of the project by permitting and supporting the installation of the project on their ranches. The support of the California Table Grape Commission, E.J. Gallo, Sun Maid Growers, NGWI, and J. Lohr Vineyards and Wines is gratefully acknowledged.

“The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.”

Regional assessment of vineyard water use in the Central Coast: The Paso Robles Groundwater Basin

Mark Battany, Viticulture/Soils Farm Advisor
UC Cooperative Extension, San Luis Obispo, CA 93401
Phone: 805-781-5948, Fax: 805-781-4316, Email: mcbattany@ucanr.edu

Irrigated vineyards in San Luis Obispo County rely primarily on groundwater sourced from on-site wells; this groundwater in turn is recharged from local rainfall. The Paso Robles Groundwater Basin is the main irrigation water source for the large expanse of irrigated vineyards east of the city of Paso Robles. Groundwater levels in the basin have often fluctuated historically in response to changes in pumping withdrawals and rainfall recharge amounts. Over the past two decades the vineyard acreage has increased substantially, while at the same time that demands for rural residential and municipal water extraction from the basin has also been increasing. This situation has led to concerns about the long-term sustainability of this water resource to provide for the needs of these diverse and competing uses.

Groundwater level measurements between 1997 and 2006 indicated that a notable decline in levels had occurred in the region directly east of the city of Paso Robles (Todd Engineers, 2007). Subsequently, a sub-region within the groundwater basin that encompassed this area of decline was designated as the “Estrella-Creston Area of Concern.” More recent measurements have indicated that the groundwater level declines are more widespread in the groundwater basin.

Irrigation of crops, primarily vineyards, is considered to be the single largest use of water from the groundwater basin in this area, but little information exists regarding the actual quantity of water being used on average by vineyards. Rough estimates of vineyard water use have been employed in past modeling work of the groundwater basin, but having more precise information on vineyard water use will improve model accuracy (Yates, 2010), and will thereby ensure that future planning and regulatory decisions are based on the most reliable information possible.

To address this need for more detailed information regarding local water use by vineyards, in late 2009 a project was initiated to measure the amount of irrigation water being used by vineyards within the “Area of Concern” (Battany, 2010). This project has been conducted by the UC Cooperative Extension, supported by a donation from the Paso Robles Wine Country Alliance and the cooperation of many area growers who have voluntarily allowed irrigation monitoring to occur on their property. This project was intended to be conducted for a minimum of three years, to evaluate water use as affected by the highly variable winter rainfall conditions. The measurement goals are simple; to determine the average annual water use by the vineyards within the target area, and to determine the timing when this usage occurs. Monitoring devices were installed in 84 individual vineyard blocks throughout this area, with the measurement sites having been chosen at random within each cooperating vineyard (Figure. 1).

Measurements are being taken using pressure switches plumbed into the drip irrigation line. A data logger records the precise time whenever each individual switch is activated or deactivated, resulting from the irrigation system being turned on or off accordingly. This produces a record of the irrigation system run time; using this time of operation, the volume of water applied is subsequently estimated by using the design flow rates of the irrigation emitters. This is not a perfect estimation, as actual flow rates do in practice vary somewhat from the design flow;

flows can be reduced due to emitter clogging and low line pressures, or increased due to high pressures, leaks and worn emitters. However, previous measurements by mobile irrigation testing labs in California have shown that the average value of a large number of flow rate assessments tends to be very close to the design rate (Figure 2). Therefore for the purposes of this study, the potential error in estimation at individual sites is a relatively minor concern as the primary goal is to estimate the average vineyard water use per year.

Sites with supplemental sprinkler irrigation systems have had two monitoring devices; one measures the operation of the drip irrigation system, and the other the operation of the sprinkler system. The volume of water applied by the sprinkler system has been estimated in a fashion similar to that of the drip system. Of the 84 vineyard blocks monitored, 22 of them had sprinkler irrigation. As part of this project, additional rainfall data has also been collected at seven sites throughout the study area. This data will characterize the rainfall conditions prior to each irrigation season, and will help determine how representative the three years of the study were compared to average rainfall years.

The data logger information has been collected at the end of each calendar year for the 2010 and 2011 seasons; the 2012 season data will be collected in early 2013. With the completion of the three years of measurements, the summary irrigation use values will be calculated. An important component of this project is that by design, the recorded water use information of the cooperators remains anonymous. This serves to encourage broader participation in the project, by removing concerns that measurements could somehow be used against participating landowners.

The project is scheduled to be continued through 2015, with measurements expanding to vineyards throughout the entire groundwater basin. This expanded project is being funded with a USDA/CDFA Specialty Crops Block Grant.

References:

Battany, M.C. 2010. Paso Robles irrigation monitoring project. Grape Notes Newsletter, March 2010. <http://ucanr.org/grapenotes>

Update for the Paso Robles Groundwater Basin. 2007. Todd Engineers, Alameda, CA. <http://www.slocountywater.org>

Yates, G. 2010. Peer Review of Paso Robles Groundwater Basin Studies. <http://www.slocountywater.org>

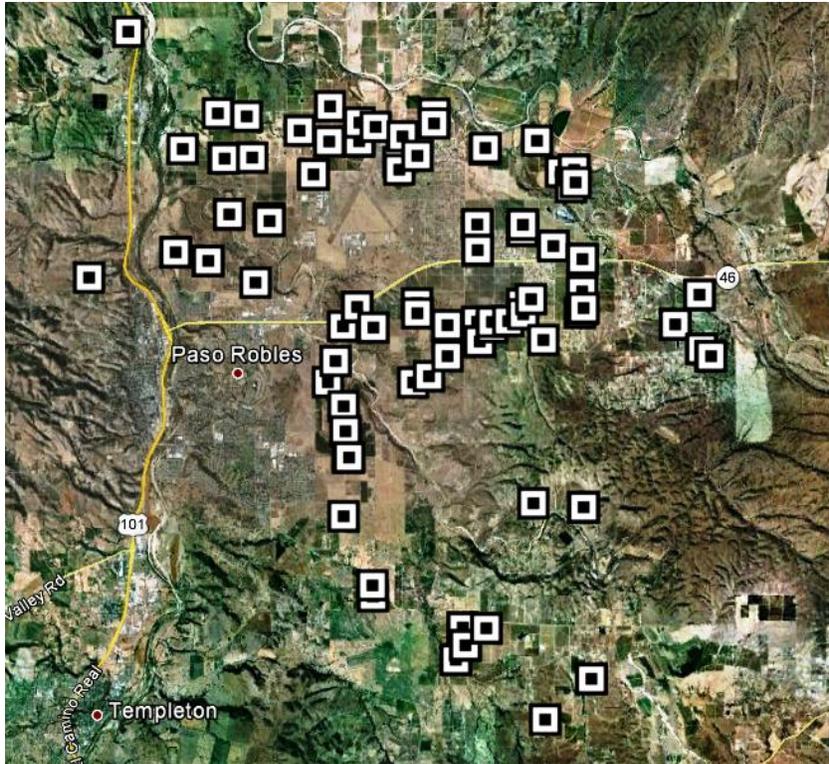


Figure 1. Location of the 84 vineyard measurement sites; all locations are within the original “Estrella-Creston Area of Concern” where the largest groundwater level declines have been observed.

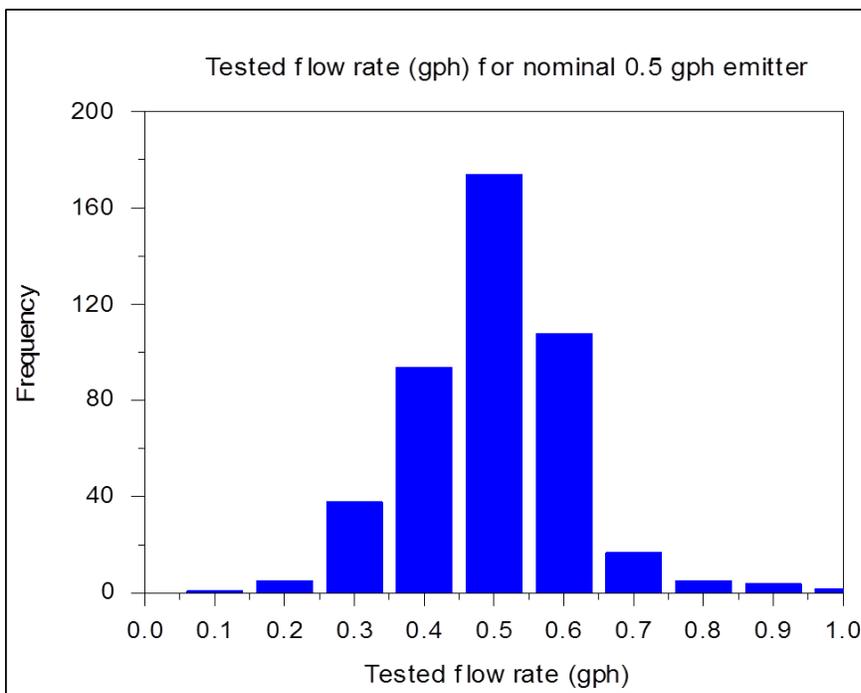


Figure 2. Summary data from tests of 113 locations by state mobile testing labs. Total number of emitters tested: 8249; Mean flow rate: 0.504 gph; Standard Deviation: 0.13 gph. Source: <http://www.itrc.org/irrevaldata/isedata.htm>



American Society of Agronomy

California Chapter

Session VI
Soil Salinity &
Managing Soil Quality

Session Chairs:

Steve Grattan

Toby O'Geen

New Soil Survey Applications to Investigate California's Soil Resource

Anthony (Toby) O'Geen, Associate Soil Resource Specialist in CE, Department of Land, Air and Water Resources, University of California, Davis, One Shields Avenue, Davis, CA 95616
Phone (530) 752-2155, atogeen@ucdavis.edu

Dylan Beaudette, USDA-NRCS, Sonora, CA Phone (209) 532-3671,
Dylan.Beaudette@ca.usda.gov

Mike Walkinshaw Department of Land, Air and Water Resources, University of California, Davis, One Shields Avenue, Davis, CA 95616, mikewalkinshaw@gmail.com

Introduction

Now that hardcopies of soil surveys are no longer in print, digital soil survey products have become the primary mechanism of data delivery. While the National Cooperative Soil Survey has made considerable progress in expanding the delivery of soil survey data via the internet, web-based interfaces to soils information do not lend themselves to field uses, and are not always easily adopted by non-technical users. In 2010, the California Soil Resource Laboratory at UC Davis developed an online Soil Survey (SoilWeb) and GPS-enabled smartphone applications to support on-demand access to soil survey information anywhere (with cell phone coverage) in the U.S.A. This presentation will showcase the most recent revisions and improvements to SoilWeb.

In collaboration with the USDA-NRCS, SoilWeb has been revised into a web-based interface instead of native apps for smartphones. This latest version of SoilWeb works across any device that can receive an internet connection, desktops, tablets and all smartphones. New features include a dynamically updated map interface, more highly integrated data summaries, revised graphical representations of soil properties and a soil map unit extent tool.

Design

The SoilWeb app uses a variety of open source technologies working together. On the web server, soil survey data obtained from USDA-NRCS are stored in PostGIS, an extension to the popular relational database management system PostgreSQL. PostGIS "spatially enables" the database, providing an efficient way to store the geographic data, and allowing for location-based queries. The widely used server scripting language PHP is used to query the database for soil survey map unit and component data as needed. MapServer, another open source project, is responsible for generating map tiles from the geographic data. This script on the server renders images depicting the map unit boundaries which are then overlain onto the interactive Google map.

In the user's web browser, the Google Maps API provides the foundation for the interactive map consisting of soil survey linework, Google imagery and contextual information such as places and roads. The API provides a highly customizable map interface, excellent satellite imagery and other basemaps, a geocoding service for locating the user's area of interest, and functionality to incorporate the map tiles delivered by MapServer. The JavaScript library jQuery is used to facilitate the management of the dynamic user interface, from showing and hiding page overlays to interacting with the server for data requests. Lastly, the app takes advantage of two features

present in modern web browsers: the Geolocation API, which can determine the user's current location; and media queries, which are important for delivering different styling rules to the web page so that the app is easily viewed across a variety of devices.

Summary

This technology is generating a tremendous amount of excitement and is having a significant impact on the use of soil survey in California and across the U.S (Figs 1 and 2). In addition to being highlighted at the Rio+20 meetings, several newspapers, trade magazines have highlighted our apps. SoilWeb receives hundreds of requests for soils information per day.

SoilWeb was designed for a wide range of users including growers, educators, students, consultants, soil survey staff, agronomists, as well as the general public. The intent was to enable more people to access, and more importantly, apply soil survey information in a manner that best accommodates how soil surveys are used-- *in the field*. Several additional features are currently planned for future releases of the application including queries based on user-defined geographic coordinates, maps of soil properties, and enhanced soil science educational material. The smartphone application is available at no cost at <http://ucanr.edu/soilweb>. Links to other soil survey tools can be found at <http://casoilresource.lawr.ucdavis.edu/soilweb/>.

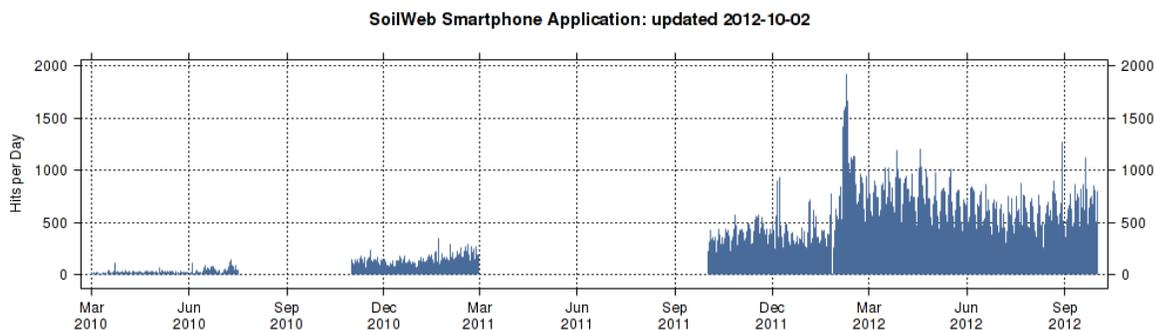


Figure 1. SoilWeb usage statistics.

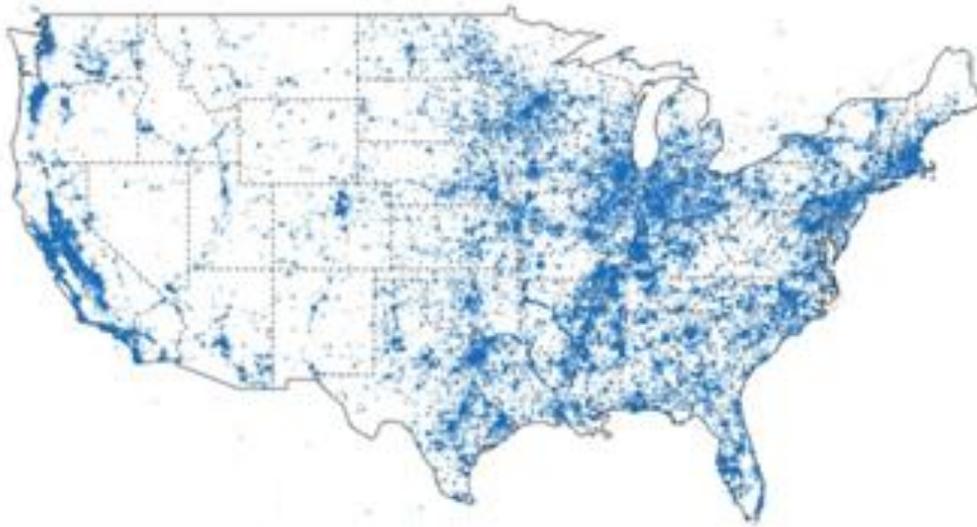


Figure 2. Geographic extent of SoilWeb users in U.S.

Literature Cited

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

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

Herding Nitrogen, Herding Cats: Recent Improvements, Continuing Challenges, and Possible Solutions for California Agriculture

Stuart Pettygrove, Cooperative Extension Soils Specialist,
and Kristin Dzurella, Analyst
Land, Air & Water Resources, University of California, Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-2533, gspettygrove@ucdavis.edu

In the 2012 UC Davis report “Addressing Nitrate in California’s Drinking Water” which covers 3.12 million acres in the southern half of the San Joaquin Valley and the Salinas Valley, the authors estimate that in recent years more than 50% of all nitrogen applied to cropland has been leached past the root zone and will eventually reach the groundwater (Harter and Lund, 2012). This is compared to only 34% of all N inputs removed from fields in the harvested crops and 15% lost to the atmosphere or in runoff (Table 1).

There are several ways to put these numbers into perspective. One is that the N inputs from all sources amount to 320% of estimated crop N harvest removal. This can be compared to a limit of 140% imposed on dairy farmers by the Central Valley Regional Water Quality Control Board in its 2007 General Order Waste Discharge Requirements -- a regulation that is intended to eventually reduce nitrate leaching from dairy crop fields. A second perspective on the estimated amount of nitrate leached is that if it were carried below the root zone in 12 inches of water (a reasonable guess at the average amount of water that percolates below crop fields annually), the resulting concentration in the percolate would be 46 mg/liter nitrate-N, which is 4.6 times the nitrate drinking water standard of 10 mg/liter nitrate-N.

These numbers, of course, tell us very little about the sources and spatial distribution of nitrate leaching losses – Salinas Valley vs. San Joaquin Valley, almonds vs. lettuce vs. silage corn, or about differences due to soils and the actual management practices on individual farms. Obviously, N management and cropping practices, as well as soil characteristics, differ tremendously within the region. But these figures do support the contention, documented elsewhere in the UC Davis report, that irrigated cropland accounts for 96% of nitrate found in groundwater in the study area. Of special note is that the increase, beginning in the 1990s, in dairy manure N applied to cropland coincides with an increasing imbalance between total N applied and crop N harvest removal.

Current Best Management Practices for Reducing Nitrate Leaching

No one practice or set of practices -- imposed by regulation or adopted voluntarily -- will work across the diverse cropping systems in California to reduce leaching of nitrate. Tools and approaches must be tailored to individual situations.

A first step in identifying appropriate practices is to focus attention on the crop species, irrigation system types, and soils that present the greatest risk of nitrate leaching. The UC Nitrate Hazard Index provides a simple method for identifying the combinations of crop, soil, and irrigation system that present the greatest hazard (Wu et al., 2005). If the hazard index value suggests a low risk of nitrate leaching loss, the grower must still implement sound management practices, but extraordinary procedures are not required. Where risk is high, careful attention and more precise management are needed, and “typical” management may not suffice. For

example, winegrapes have relatively low N requirements, and their deep roots and the common use of drip irrigation result in little deep percolation and a low risk of nitrate leaching loss. In contrast, attention to optimizing crop recovery of applied N is more critical in spinach. This crop is often grown on well-drained loamy soils and it is usually sprinkler irrigated throughout the crop cycle; it has shallow roots, and it requires high levels of N up to the time of harvest. Improvements to groundwater quality can be achieved by targeting mitigation efforts to such hazardous situations.

Over the past 40 years, technologies that favor efficient use of nitrogen by crops have been developed in California (Table 2). Some of these are in common use by farmers, and some have potential for expanded use. Among the important practices adopted by farmers in recent years are the following:

- Conversion from furrow and other surface irrigation methods to drip and microsprinkler systems, which have the potential to reduce deep percolation. Use of drip does not guarantee less deep percolation losses. Some drip systems are operated on “autopilot” and apply far more water than needed to meet crop demand. Also, the cost of conversion so far has not allowed for these systems to be used on most agronomic crops, including the dairy forages.
- N fertigation through drip lines and microsprinklers, making it much easier to precisely match N fertilizer applications to crop N demand.
- Weather based irrigation scheduling tools, such as the California Irrigation Management Irrigation System (CIMIS), which alone or in combination with monitoring of soil or plant water status, can help growers with irrigation timing and amount decisions.
- Soil nitrate testing to guide N fertilizer rates and timing.
- Use of cover cropping and development by the University of California of simple methods for estimating the N content of cover crop biomass at the time of incorporation.
- Measurement of irrigation water nitrate content and consideration of this to adjust N fertilizer application rates.

For increased farmer adoption of the nitrogen-efficient practices listed in Table 2, barriers to implementation must be overcome. These include obvious barriers like increased management or labor costs and less-obvious constraints such as “ranch logistics” and land tenure issues. An example of ranch logistics as a barrier is when an irrigation district’s delivery schedule or the farmer’s pumping capacity restricts the ability to adjust the timing of irrigations on individual fields. Another type of logistical constraint is created by spatial variability, e.g., of soil infiltration rate and water-holding capacity. This type of spatial variability imposes an upper limit on irrigation system performance.

Near-Term and Not-so-Near Term Solutions

Newer approaches not listed in Table 2 or that require additional research and development include the following examples:

- Increased use by farmers of adaptive management tools such as field nitrogen budgets or balance sheets, which over time can be used to track improvements in crop N use efficiency; also end-of-season plant tissue N or soil nitrate testing.

- Web-based tools to facilitate the tracking by managers of irrigation and nitrogen on a large number of fields or sub-field blocks. For annual cropping systems, increased use of soil nitrate testing, including in some situations use of quick test methods has already been developed for coastal vegetable production, but improved methods for data management and delivery of the information to field managers will help routinize the use of these practices.
- Decision aids based on computer models that include temperature as an input variable to forecast N mineralization from soil organic matter, manure, and other organic amendments. Predicting N mineralization remains a big challenge for agriculture. For models to be anything more than fancy guess work, they must be calibrated to specific crop rotations, soils, and tillage regimes. On-farm, zero-N fertilizer plots are one approach to calibration.
- Advances in equipment that would lower the cost of center pivot, linear move, and drip irrigation systems, so that these would become economical to use on lower value agronomic crops. This is a well-recognized need. Small improvements in equipment or techniques could allow increased adoption on some crops where this is not economical now.
- Economical methods for recycling of solid and liquid dairy manure into more concentrated, uniform products that are more reliable for use as fertilizers and soil amendments in a wider variety of cropping systems.

Farmers in California probably are not going to stay in business by going back to older rotations and practices. But it cannot hurt here to think about the benefits (less nitrate leaching losses) of some of the older practices and consider whether more dramatic changes in our crop and livestock farms might have a future. For example:

- Bring back sugarbeets (low N-requiring) or increase acreage of safflower and other tap-rooted crop species that require low N or are effective N scavengers.
- Increase (or slow the decline of) soil organic matter levels by greater use of cover cropping, compost applications, and reduced tillage. Cover cropping and compost additions are already in common use in organic farming.

Assessing the impact of crop rotation and tillage on soil organic matter levels is complicated. It is not certain how reduced tillage will affect soil organic matter levels under California conditions. In an 11-yr study in Michigan, high cropping intensity and chisel plow management increased soil organic matter levels compared to the preceding alfalfa management (Fortuna et al., 2003), contrary to what might be expected with the more intense tillage. Closer to home, in a 9-year study at the UC Davis Sustainable Agriculture Farming Systems experiment, soil nitrate leaching losses were greatly reduced and soil N content was increased in an organic annual cropping system compared to conventional systems (Poudel et al., 2001). Some studies show that addition of crop residues and organic amendments shifts the soil pore size distribution such that water and nutrients are more effectively retained while the soil is still adequately aerated.

What are some “blue sky” changes that could be considered for dairy farmers to reduce nitrate leaching from crop fields that receive manure and lagoon water? All milk cow dairy farmers in the Central Valley are now required by regulation to follow a stringent set of monitoring and reporting protocols, but what exactly they can do to comply with the regulatory limit to total N applications to fields is not at all clear. Lagoon water cannot practically be

transported far from the point of generation – usually not more than a mile or two; and even the best flush manure collection systems produce “nutrient water” that is highly variable in composition. Some newer dairies have been designed to handle most of the manure as a slurry or scraped solid rather than a dilute wastewater. Other dramatic approaches under consideration include biodigesters (converting manure to a smaller volume of nutrient-rich digester residue), development of systems for applying dairy lagoon water to fields through center pivot irrigation lines, and inclusion of perennial grass forages in dairy crop rotations. These approaches have been tried by dairy farmers but for various reasons so far have not been widely adopted.

Groundwater Quality: It’s not just about farming practices

Groundwater aquifers in the more arid parts of California where the land is intensively farmed, e.g., much of the San Joaquin Valley, have for several decades been recharged mainly by irrigation water that percolates past the crop root zone. As growers manage water more tightly -- for example, by converting to drip irrigation and using weather-based irrigation scheduling – the volume of recharge from cropland will be decreased. Even if farmers reduce the mass quantity of N leached below the root zone, the concentration of nitrate in the percolate will almost certainly still exceed the nitrate drinking water standard. For groundwater quality to be improved, not only must there be a reduction in nitrate leaching, but there must be at least some clean recharge entering aquifers. If, as seems likely to happen, all of the water “saved” by on-farm irrigation improvements is used to irrigate additional acres or is transported out of the basin, we can speculate that aquifer quality will continue to be degraded. This problem is where the separate topics of water supply quantity and water quality come together.

Literature Cited

- Dzurella, K.N. et al. 2012. Nitrogen source reduction to protect groundwater quality. Technical Report 3 *In* Addressing nitrate in California’s drinking water with a focus on Tulare Lake Basin and Salinas Valley groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis. <http://groundwaternitrate.ucdavis.edu>.
- Fortuna, A., R.R. Harwood, and E.A. Paul. 2003. The effects of compost and crop rotations on carbon turnover and the particulate organic matter fraction. *Soil Sci.* 168(6):434-444.
- Harter, T., J. Lund et al. 2012. Addressing nitrate in California’s drinking water with a focus on Tulare Lake Basin and Salinas Valley groundwater. Report for the State Water Resources Control Board Report to the Legislature. Center for Watershed Sciences, University of California, Davis. <http://groundwaternitrate.ucdavis.edu>.
- Poudel, D.D., W.R. Horwath, J.P. Mitchell, S.R. Temple. 2001. Impact of cropping systems on soil nitrogen storage and loss. *Agricultural Systems* 68:253-268.
- Wu, L., J. Letey, C. French, Y. Wood, and D. Birkle. 2005. Nitrate leaching hazard index developed for irrigated agriculture. *J Soil Water Conservation* 60(4):90-95. Also see http://ucanr.edu/sites/wrc/Programs/Water_Quality/Nitrate_Groundwater_Pollution_Hazard_Index/.

Table 1. Nitrogen mass balance for 3.12 million acres of irrigated cropland in the Tulare Lake Basin and Salinas Valley. (Derived from Fig. ES-2, page 4, Harter and Lund, 2012.)

	N inputs per year			N outputs per year	
	1,000 tons actual N	% of inputs		1,000 tons actual N	% of inputs
Total	420	100	Total	420	100
Fertilizer	225	54	Crop harvest removal	130	34
Dairy manure ²	140	33	Nitrate leaching loss	195	51
Other ¹	55	13	Loss via runoff and to atmosphere	56	15

¹Irrigation water, wastewater, food processing wastes, biosolids, non-dairy manure, atmospheric deposition

²Estimate of N excreted by animals minus N volatilized in animal housing and manure storage areas

Table 2. Crop management practices contributing to low nitrate leaching and barriers to increased farmer adoption. Some of the listed practices are already in widespread use in California. Modified from Dzurella et al. 2012.

Management practices contributing to low nitrate leaching	Barriers to increased adoption
<i>YQ= risk to yield, quality or marketability, CC=capital cost, OC=operational cost, RL=ranch logistics, LT=land tenure issues, ED=need education, training, IT=technology needs further development</i>	
Irrigation system evaluation and monitoring	
Conduct irrigation system performance evaluation	OC, LT, ED
Use flow meters or other measuring devices to track water volume applied to each field at each irrigation	CC, OC, ED
Conduct pump performance tests	OC
Irrigation scheduling	
Use weather-based irrigation scheduling	OC, RL, ED, IT
Use plant-based irrigation scheduling	OC, RL, ED
Use soil moisture content to guide irrigation timing and amount	OC, RL, ED
Avoid heavy pre-plant or fallow period irrigations	YQ, RL, ED
Improve surface gravity system design and operation	
Convert to surge irrigation if appropriate	CC, OC, RL, ED
Use high flow rates initially, then cut back to finish off the irrigation	OC, RL, ED
Reduce irrigation run distances and decrease set times	YQ, CC, OC, LT, ED
Increase flow uniformity among furrows, e.g., by compacting furrows, use of "torpedoes"	OC
Grade fields as uniformly as possible	OC
Where high uniformity and efficiency are not possible, convert to drip, center pivot or linear move systems	CC, OC, LT, ED
Improve sprinkler system design and operation	
Monitor flow and pressure variation	OC
Repair leaks and replace malfunctioning and worn sprinkler nozzles	CC, OC, ED
Operate sprinklers during the least windy periods	RL
Use flow control nozzles when pressure variation is high	CC, LT, ED
Improve drip and microsprinkler system design and operation	
Use appropriate lateral hose lengths to improve uniformity	ED
Check for clogging potential and prevent or correct clogging	OC, ED
Improve rate, timing, placement of N fertilizers	
Adjust N fertilizer application rates and timing based on soil nitrate testing	YQ OC, ED
Adjust timing of N fertilization based on plant tissue analysis	YQ, OC, ED
Apply fertilizer N in small multiple doses rather than single large doses	OC, ED
Measure N content of irrigation water and adjust fertilizer rates accordingly	OC LT, ED
Vary N rates within large fields according to expected need, rather than applying the same rate everywhere	OC, ED, IT
When N fertigating in surface gravity systems, use delayed injection procedure	OC, RL, ED, IT

Develop N budget that includes crop N harvest removal, supply of N from soil, and other inputs	OC, ED
Use controlled release fertilizers, nitrification inhibitors and urease inhibitors	YQ, CC, ED, IT
Improve rate, timing, placement of animal manure applications	
Apply moderate rates of manure and compost, meet peak demands with high available-N content materials	OC, ED
Incorporate solid manure immediately to decrease NH ₃ volatilization loss	OC, ED
When applying liquid manure in surface gravity irrigation system, use delayed injection procedure to improve application uniformity	OC, RL, ED
Use quick test methods to monitor dairy lagoon water before and during application, and adjust accordingly	OC, ED
Develop N budget that includes crop N harvest removal, supply of N from manure and other inputs	OC, ED, IT
Calibrate solid manure and compost spreaders	OC, ED
Modify crop rotation	
Grow cover crops	YQ, CC, OC, RL, ED, IT
Include perennials or deep-rooted annual "N scavenger" species in crop rotations	YQ, CC, OC, RL, LT
Grow more crops per year, e.g., dairy forage triple crop rotation	OC, RL
Avoid fertilizer and manure discharges during transport, storage and application	
Do not overfill trailers or tanks. Cap or cover loads	ED
When transferring fertilizer, take care not to allow materials to accumulate on the soil	ED
Maintain all fertilizer storage facilities and protect them from the weather	CC, OC, ED
Clean up fertilizer spills promptly	ED
Shut off fertilizer applicators during turns and use check valves	OC, ED
Maintain proper calibration of fertilizer application equipment	ED
Protect wellheads and prevent backflow	ED
Distribute rinse water from fertilizer application equipment evenly throughout field	OC, ED
Avoid manure spills/discharges during transport, storage and application	ED
<i>YQ= risk to yield, quality or marketability, CC=capital cost, OC=operational cost, RL=ranch logistics, LT=land tenure issues, ED=need education, training, IT=technology needs further development</i>	

Beyond Conservation Tillage: Merging Technologies for Greater Efficiencies

Jeff Mitchell, Cropping Systems Specialist, Department of Plant Sciences, University of California, Davis, 9240 S. Riverbend Avenue, Parlier, CA 93648
Phone (559) 646-65565, FAX (559) 646-6593, jpmitchell@ucdavis.edu

Introduction

The development of annual cropping systems in California's Central Valley (CV) is nothing short of a phenomenal success story that has been built upon numerous innovations and technological advances. Over the past 90 years, yields of several CV annual crops have increased several hundred percent (USDA, 2012). While the productive capacity of the CV rests in large measure upon the region's Mediterranean climate with rain-free summer growing seasons and sustained breeding and genetic improvement efforts that have led to highly adapted varieties, a number of advances in production technology have also significantly contributed to this increased productivity (Table 1).

Table 1. Evolution of agricultural technologies with strong impact on agronomic productivity in California's Central Valley (Mitchell et al., 2012a and b)

- 1930's "Pump Era" and expanded availability of water for irrigation
- 1950's Wider availability of herbicides
- 1963 Central Valley Improvement Project
- 1990's Widespread availability of glyphosate-resistant seed
- 1993 Availability of various minimum tillage implements
- 1998 Conservation Tillage (CT) Workgroup formed
- 2003 Widespread use of drip irrigation
- 2005 Widespread use of GPS

Tillage Management in the Central Valley

Until recently, tillage and cultivation practices that are used throughout the production season of most CV annual crops have changed relatively little during the last half of the 20th century (Mitchell et al., 2012a and b). Despite the recent availability of incentives programs such as the USDA Natural Resources Conservation Service's Environmental Quality Incentives Program (EQIP) to encourage tillage reduction, as well as the increasing cost of intensive tillage, the majority of CV production systems still rely on traditional, multiple-pass tillage practices largely because these systems are what producers are familiar with and because they have provided reliable productivity in the past (Mitchell et al., 2012a).

During the past decade, however, experience with a number of tillage system alternatives for CV crop production has increased (Mitchell et al., 2012a). The majority of 'minimum tillage' (Mitchell et al., 2012a) approaches that have been adopted still tend to rely on 'clean cultivation' and residue-free conditions.

Conservation Agriculture: A New Production Paradigm for the Central Valley

In 1998, the Conservation Tillage Workgroup was established to develop information and to expand the adoption of conservation tillage (CT) systems in the CV. In 2012, the Workgroup expanded the scope of the work it had begun on CT to address what might be more generally termed ‘conservation agriculture,’ (CA) or ‘sustainable production intensification’ (Friedrich and Kassam, 2011) cropping systems. Broadly defined, CA represents a set of practices or principles that include reduced soil disturbance, preservation of surface residues, diverse crop rotations, integrated pest management, cover crops, precision irrigation, and controlled traffic (<http://casi.ucanr.edu/?blogpost+8115&blogasset+14128>). In theory, when these practices are used together, they increase the competitiveness and sustainability of production systems. The full integration of these practices, however, has not been widely realized in California despite the fact that they are widely recognized to lead to improved, more efficient, and less leaky systems (Hobbs et al., 2008, Friedrich and Kassam, 2011). The term ‘CA’ enjoys broad recognition and understanding in other parts of the US and internationally, but it is a relatively new addition to California’s ag lexicon. Various reports have tracked dramatic increases in the adoption of CA in South America, Canada, the Midwest and Southeast US, and Australia (Derpsch and Friedrich (<http://www.rolf-derpsch.com/>)). In regions of the world where CA systems are common, generating and preserving residues are an indispensable part of management and major, even primary goals of sustainable production (Crovetto, 1996, 2006).

An important aspect of CA is that it attempts to ‘take the long view’ by thinking broadly and over longer time horizons with its research agenda and practices. “If a given practice under consideration is used for 100 years, for instance, what would the social and environmental landscape look like?” (Personal communication, D. Beck, 2011).

Merging Conservation Agriculture Technologies in the Central Valley

The Conservation Agriculture Systems Innovation Center in Five Points, CA has been working to develop information on CA systems for a number of CV rotation applications now for several years. This work is aimed at coupling appropriate technologies such as precision overhead and subsurface drip irrigation, flat planting, GPS, no-till, residue preservation, year-round soil cover, and sensor-based irrigation scheduling. We have reported findings and outcomes from several studies that have shown both the promise as well as the challenges of adapting these production practices to mainstream CV rotations. To date, three major challenges have surfaced from this work. First, while CA practices have been successfully applied to a number of CV crops, certain crops present greater challenges to adoption. Tomatoes, for example, have presented challenges in terms of both CT and overhead irrigation management. A second general challenge is crop stand establishment. Achieving uniform, consistent, and robust initial crop stands has been difficult in very high residues for a number of crops including cotton, wheat and tomatoes. Lastly is the fact that to date there is not yet a sufficient enough ‘critical mass’ of CA expertise in the CV that has developed to share experience and that can help with successful CA adoption. More information on emerging CA systems is available at the CASI website (<http://casi.ucanr.edu/>).

Literature Cited

Crovetto, C. 1996. Stubble over the soil: The vital role of plant residue in soil management to improve soil quality. *Am. Soc, Agron., Madison, WI.* 241 p.

- Crovetto, C. 2006. No Tillage: The relationship between no-tillage, crop residues, plants and soil nutrition. Hualpen, Chile. Trama Impresores. 216 p.
- Derpsch, Rolf and Theodor Friedrich. 2012. Global overview of conservation agriculture adoption. <http://www.rolf-derpsch.com/>
- Friedrich, Theodor and Amir Kassam. 2011. Mechanization and the global development of conservation agriculture. 23rd Annual Saskatoon Soil Conservation Agriculture Conference, Saskatoon, Canada. January 13, 2011.
- Hobbs, Peter R., Ken Sayre, and Raj Gupta. 2008. The role of conservation agriculture in sustainable agriculture. Phil. Trans. R. Soc. 363:543-555.
- Mitchell, Jeffrey P., Purnendu N. Singh, Wesley W. Wallender, Daniel S. Munk, Jon F. Wroble, William R. Horwath, Philip Hogan, Robert Roy and Blaine R. Hanson. 2012. No-tillage and high-residue practices reduce soil water evaporation. California Agriculture Volume 66, Number 2:55-61.
- Mitchell, Jeffrey P., Lyle Carter, Dan Munk, Karen Klonsky, Robert Hutmacher, Anil Shrestha, Rich DeMoura, and Jon Wroble. 2012. Conservation tillage systems for cotton advance in the San Joaquin Valley. California Agriculture. Volume 66, Number 3:108-115.
- Mitchell, J.P., K.M. Klonsky, E.M. Miyao, B.J. Aegerter, A. Shrestha, D.S. Munk, K.J. Hembree, N.M. Madden and T. Turini. 2012. Evolution of conservation tillage systems for processing tomato in California's Central Valley. HortTechnology 22(5):1-10.

Reducing Sediment loss and Protecting Water Quality in Coastal Vegetables

Michael Cahn, UC Cooperative Extension, Monterey County
1432 Abbott St, Salinas CA 93901
Phone 831-759-7377, FAX 831-758-3018, mdcahn@ucdavis.edu

Richard Smith, UC Cooperative Extension, Monterey County
1432 Abbott St, Salinas CA 93901
Phone 831-759-7357, FAX 831-758-3018, rifsmith@ucdavis.edu

Introduction

Run-off from vegetable fields on the central coast of California has resulted in water quality impairments from sediment, nutrients (N and P), pesticides and bacteria in surface water. Many of the watersheds on the central coast drain into the Monterey Bay National Marine Sanctuary, the largest marine sanctuary on the US mainland, and habitat of 34 species of marine mammals. Both federal and state water quality regulations require that growers implement practices that minimize agricultural impacts on water quality of receiving waters.

The cause of agricultural run-off on the central coast is a combination of factors, including the mix of crops produced, the method of irrigating, and the physical properties of the soils. The central coast is the major production region for leafy green vegetables, producing for approximately 70% of the US market with an annual value of more than \$2 billion. Quality and yield of leafy green crops such as lettuce and spinach can suffer from small deficits in soil moisture. Consequently, during the irrigation season most growers err on over- than under-applying water. On many soil types in this region, the use of overhead sprinklers can lead to significant crusting and aggravate run-off problems. In addition, the tendency of growers to maintain soils at high moisture contents causes soil to saturate during irrigation events, reducing the infiltration rate of the soil, and increasing run-off. We have measured run-off volumes equal to 25% of the applied water under overhead sprinklers, especially during crop establishment when soil is maintained close to saturation. Sprinkler induced run-off in this region can have high concentrations of suspended sediments and associated nutrients (Table 1). Total P concentration in irrigation run-off from 6 coastal soils was found to be correlated to suspended sediment concentration (Fig. 1). The concentration of sediment bound pesticides such as pyrethroids is also correlated to suspended sediment concentration in run-off.

Run-off volumes from vegetable fields can be significant during the winter storm events on the central coast. Most of vegetable fields in this region are fallowed between November and February. Growers are reluctant to plant winter cover crops because of the expense and time required to incorporate cover crop biomass before planting a vegetable crop in the early winter and spring. In most cases vegetable fields are listed into peaked beds in the fall and maintained bare with either herbicide sprays or cultivation. In the Salinas Valley, winter storms greater than 1 to 2 inches can result in considerable run-off from fallowed vegetable fields, leading to flooding of county roads and highways, as well as soil erosion and water quality impacts.

UC Cooperative Extension research has evaluated multiple approaches of minimizing agricultural run-off and associated water quality impacts during the past 10 years. These strategies have ranged from applying polymers to improving irrigation efficiency, and have

demonstrated that many management tools are available for growers to use to minimize run-off and impacts to water quality.

Soil Polymers Polyacrylamide (PAM) polymers have been used for soil erosion control since the 1990's. PAM polymers are long-chained molecules (10 to 15 Mg mole⁻¹) that can increase aggregate stability of soil, and have been successfully used in furrow irrigation to minimize sediment losses in the Northwest of the US (Lentz and Sokja, 1996). Less information exists on using PAM for overhead sprinkler irrigation to minimize suspended sediments in run-off. Our past field trials have shown that liquid formulations of PAM can be effective in reducing sediment loss from sprinkler irrigated vegetable fields when injected directly into the irrigation water at concentrations of 5 ppm (Cahn et al. 2004). Reduction in suspended sediment concentration in run-off depends on the soil characteristics and slope, but generally ranges from 85% to 95% (Table 2). PAM is most effective in reducing sediment loss during the first 3 to 4 irrigations when fine soil particles are easily suspended in run-off water. In addition to reducing sediment concentration, our trials have demonstrated approximately 70% reduction in total P and total N concentration in run-off. We have also demonstrated that PAM is an effective means to reduce pyrethroid concentration in sprinkler run-off. PAM does not appear to be effective in reducing soluble nutrient (ortho-phosphate and nitrate) and water soluble pesticide concentrations in run-off, nor in reducing *E. coli* concentration.

Vegetated water-ways. Most central coast farms have bare (non-vegetated) drainage ditches for channeling run-off. Vegetation can stabilize and prevent the sides and the bottom of the ditch from eroding during high-flow storm events. During the irrigation season when run-off events are less intense, vegetation may slow the flow rate of the tail-water, allowing it to infiltrate and drop out suspended particles. Organic matter contained in vegetation and in plant residue in the ditch may also sequester soluble pesticides. Two replicated field trials that we conducted in the Salinas Valley showed inconsistent water quality benefits from treating sprinkler run-off using 170 ft long vegetated ditches. We concluded that the sediment load and flow rates were often too high to measure a significant reduction in suspended sediment concentration between the inlet and outlet of the ditches. In addition, the ditches were narrow (3 meters in width) and did not spread the water out across the ditch bottom sufficiently to reduce the flow rate. Similar studies conducted in Yolo and Tehama counties showed significant water quality benefits from vegetated ditches of similar dimensions when used with run-off from furrow irrigation which had a much lower suspended sediment concentration than run-off from sprinklers (Long et al. 2010). A preliminary trial conducted in the Salinas Valley using a 5-m wide, vegetated ditch in 2011, infiltrated 44% of run-off volume in a distance of 250 ft and reduced chlorpyrifos concentration by 54%. One of the major limitations to using vegetated ditches on farms where leafy greens are produced is concern that they harbor rodents, birds, and amphibians that could become a food safety liability. Though the California leafy green marketing agreement does not prohibit vegetated ditches (LGMA 2012), many shippers and handlers of leafy green products impose more stringent requirements, which have discouraged grower interest in establishing these practices.

Sediment traps and basins These structures are designed to slow the flow of run-off, allowing time for suspended sediments to settle. Designs vary considerably depending on the intended volume to be treated, but generally shallow structures with sufficient volume to retain run-off for

several hours are most effective in removing sediments. Clay-sized particles can be difficult to settle in less than a day; consequently, sediment basins are often not effective in removing fine particles and associated nutrients and pesticides without addition of flocculent chemicals such as PAM. Sediment traps are generally much smaller in size than basins and can be used to capture sediments from low to moderate run-off volumes. They are generally designed with a shallow depth so that captured sediment can be periodically removed using a small tractor or backhoe. Trials we conducted in 2006 showed little reduction in suspended sediments when sprinkler run-off was treated with sediment traps measuring 7.5 ft × 35 ft × 2 ft. Suspended sediment concentrations in sprinkler-induced run-off were greater than 1500 mg L⁻¹ and the retention time in the traps was less than 45 minutes. Sediment traps are effective in capturing large-sized sand and silt particles, which rapidly settle. Since removing trapped sand and silt from these structures is a relatively simple operation, they are useful for pre-treating run-off before flowing into a vegetated ditch, where removal of sand and silt is more difficult.

Low residue cover crops. One strategy for using winter cover crops for water quality protection on the central coast is to limit the biomass of these crops using herbicides so that the residue decomposes before planting a vegetable crop in the spring. The cover crop is also planted on the listed beds so that extra tillage is not required to incorporate the plant residues. We conducted a field trial in the Salinas valley in 2010 comparing: 1. rye cover crop planted on listed beds and furrows, 2. triticale planted only in the furrows (listed beds were left bare), and 3. bare, unplanted control treatment. The cover crops were killed with herbicide 55 days after planting. Seasonal storm water run-off was reduced by 95% and 80%, respectively for the rye and triticale treatments. Sediment loss was reduced by 99% and 95%, respectively for the rye and triticale treatments (Fig. 2). Similar trials conducted in during the winter of the subsequent year did not demonstrate the same water quality benefits from low residue cover crops. Less run-off was measured in all treatments due to the use of 80-inch wide beds, and early rains immediately after planting during November, crusted the soil, minimize the effect of the plant residue on infiltration. A key lesson of this trial was the importance of planting winter cover crops early so that the soil can be protected from crusting. Further information about low residue cover crops can be found at: http://www.youtube.com/watch?v=k0oVVJ_BA7s

Drip establishment of shallowly seeded vegetables. A majority of lettuce acreage on the central coast is produced using drip irrigation. However, most crops are first established with overhead sprinklers and irrigated with surface-placed drip tape after the stand is thinned. Using drip tape for germination and post-establishment of lettuce can eliminate run-off and save the costs of using sprinklers. Our previous trials have demonstrated that drip is a feasible method of germinating lettuce on soils with a medium texture (sandy loam to silt loam) and if the tape is buried at less than 3 inches below the soil surface so that the water can move laterally to the seed lines. The shallowly placed tape is sufficiently deep so it is not harmed by cultivation, and it can be retrieved after harvest and used for subsequent crops. A challenge of drip germinating vegetables is to attain a uniform stand for the entire field, especially if the soil type varies. In addition, at planting herbicides used in lettuce, such as pronamide (Kerb), may be less effective in controlling key weed species if activated with drip-applied rather than sprinkler-applied water. Growers that have used drip for germination of lettuce in commercial production generally use equal or more water than they normally apply using sprinklers.

Improving irrigation efficiency. A key strategy to reducing irrigation run-off is to improve irrigation practices. Many growers apply extra water to assure that all areas of their fields have

sufficient moisture to produce a uniform vegetable crop. Because few technical services were available on the central coast to help growers improve irrigation system uniformity, we developed a service that evaluates uniformity and design of pressurized irrigation systems and provides recommendations to the grower through a report and an in-person consultation. Following stand operating procedures that we developed for central coast crops and irrigation systems, a technician collects necessary data to determine the irrigation system uniformity and identify the main factors affecting the irrigation system performance. We have found that this type of service helps growers understand the most cost-effective solutions to improving the performance of their irrigation system. The collected data are also useful for identifying the main issues that growers face in irrigating their crops on the central coast, and have been helpful for setting research and extension priorities.

Conclusions

Although UC Cooperative has adapted and evaluated various practices that could potentially reduce sediment loss and protect water quality on the central coast, adoption of these measures by the vegetable industry has been slow. One reason is that food safety became a priority after the leafy green marketing agreement was adopted in 2007. Growers redirected resources to address and document the requirements for food safety audits. Also, growers are weary of adopting water quality practices that rely on vegetation because of potential conflicts with food safety requirements. Another important reason is that regulators have not identified sediment loss as a major priority for water quality on the central coast. The renewed agricultural discharge waiver currently emphasizes nitrate contamination of ground water and organophosphate pesticides as the most important causes of water quality impairments. Hence most growers are working on addressing these priorities. In many cases, controlling run-off and sediment loss through improved irrigation management can address many water quality impairments. Significantly reducing sediment loss from agricultural fields on the central coast is likely more feasible than accomplishing other water quality objectives emphasized by regulators, and perhaps addressing sediment loss would be a worthwhile way for the agriculture community to demonstrate their commitment to improving water quality.

References

- Cahn, M.D., H. Ajwa, R. Smith. 2004. Evaluation of polyacrylamide (PAM) for reducing sediment and nutrient concentration of tailwater from central coast vegetable fields. Proceedings of the 12th Annual Fertilizer Research and Education Program Conference. Tulare CA. November 20, 2004. p. 17-22
- Cahn, M. D., R. Smith, and S. Fennimore. 2007. Cultural strategies for germinating lettuce with drip irrigation. California Lettuce Research Board, Annual Report 2006-2007. p. 155-163.
- Leafy Greens Marketing Agreement. 2012. <http://www.caleafygreens.ca.gov>
- Lentz, R. D. and R. E. Sojka 1996. Five-year research summary using PAM in furrow irrigation. In. Managing irrigation-induced erosion and infiltration with polyacrylamide. pp. 20-26. Twin Falls ID May 6-8. University of Idaho Misc. Publ. No. 101-96.
- Long, R. F., Hanson, B.R., Fulton, A.E., Weston, D.P. 2010. Mitigation techniques reduce sediment in runoff from furrow-irrigated cropland California Agriculture, 64(3): 135-140

Table 1. Nutrient and sediment concentrations in run-off from 7 coastal fields irrigated with sprinklers.

	Total Kjeldahl N	NO ₃ -N	Soluble P	Total P	Total Dissolved Solids	Total Suspended Sediments	Turbidity
	----- mg/L -----						NTU
Average	5.18	13.60	2.40	1.75	613	1456	2215
Maximum	11.80	48.35	8.17	4.45	863	3870	4645
Minimum	2.90	1.69	0.49	0.45	464	433	503

Table 2. Comparison of nutrient and sediment concentration in sprinkler run-off for 6 sites on the central coast irrigated with and without polyacrylamide (PAM).

Treatment	Total N	NO ₃ -N	Total P	Soluble P	Total Suspended Solids	Turbidity	
	----- ppm -----					NTU	
	----- Watsonville (clay loam) -----						
PAM (5 ppm)	0.8	58.6	1.2	1.2	47	33	
Control	2.9	48.4	2.0	0.9	652	1289	
	----- Salinas (sandy loam) -----						
PAM (5 ppm)	1.4	1.7	0.7	0.7	72	63	
Control	4.2	1.7	1.9	0.7	985	2291	
	----- Salinas (sandy loam) -----						
PAM (10 ppm)	2.7	1.3	0.4	0.2	179	108	
Control	5.5	1.8	2.4	0.5	1332	3536	
	----- Chualar (loamy sand) -----						
PAM (5 ppm)	2.3	2.7	1.9	0.8	646	218	
Control	11.8	6.5	8.2	2.1	3870	503	
	----- Santa Maria (loam) -----						
PAM (5 ppm)	1.6	14.8	0.6	0.5	60	13	
Control	7.0	17.0	10.1	1.0	5930	4417	
	----- Gilroy (silt loam) -----						
PAM (4 ppm)	1.2	8.1	1.0	0.9	74	42	
Control	4.0	6.5	3.5	1.2	2057	2408	

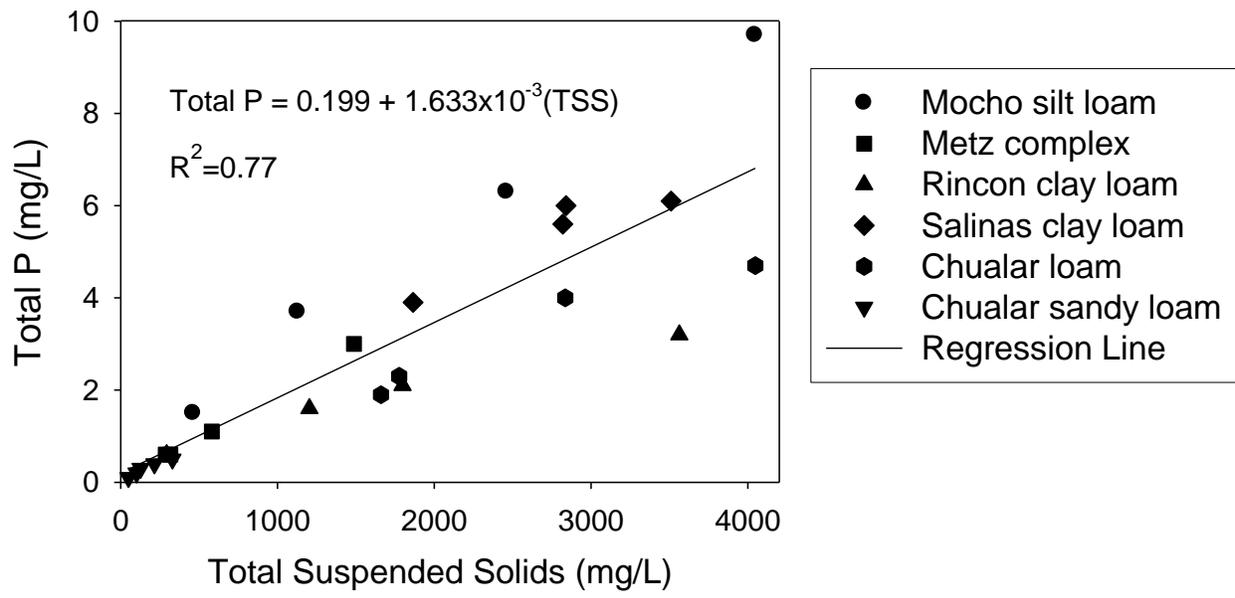


Figure 1. Relationship between suspended sediments and total phosphorus for 6 soils in the Salinas Valley.

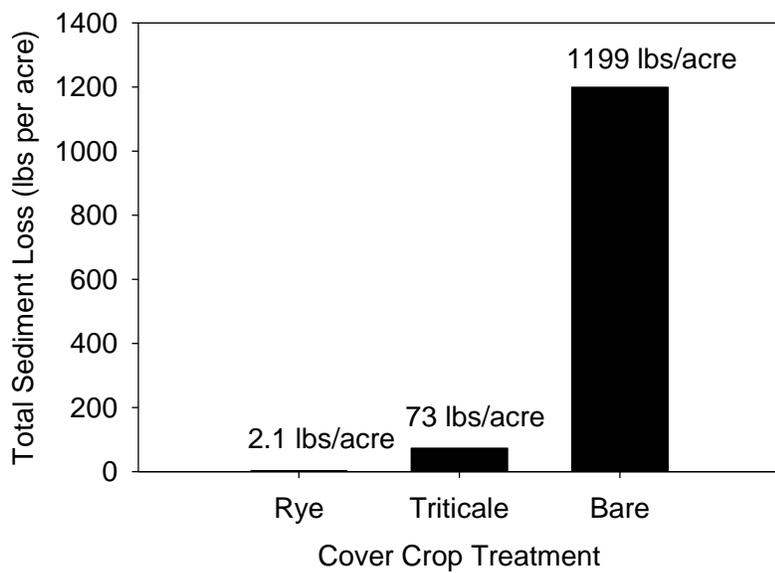


Figure 2. Sediment loss from fallow vegetable fields planted with low residue cover crops of rye (planted on beds and furrows), and triticale (planted only in furrows) compared to bare control area.

Water Quality Criteria for Use of Saline/Degraded Water for Irrigation

Donald L. Suarez, USDA/ARS Salinity Laboratory
450 Big Springs Road, Riverside CA 92507
Phone (951) 369-4815, donald.suarez@ars.usda.gov

Introduction

Current fresh water use in arid and semiarid lands is not sustainable, as use exceeds replenishment and demand for water continues to increase. The primary use of fresh water in arid and semiarid regions is for irrigation; in California approximately 70% of water use is by agriculture. Increasing demands for fresh water for municipal and industrial use throughout the world, are coupled with increasing world food needs and restrictions on surface water diversions due to environmental constraints. The irrigated acreage in the western U.S. is already decreasing due to water availability and diversion of water to other uses. Agriculture will either need to reduce acreage under irrigation, which is undesirable since it will reduce food supply, or irrigate with alternative water sources and more effectively utilize existing water supplies. Use of saline and marginal quality waters is possible, but sustained use requires consideration of the impacts of these waters on both crop production and maintenance of good soil physical properties. In many instances waters previously considered not useable or impractical for irrigation can be used with careful management. Earlier water criteria may in some instances be overly conservative due to simplifying assumptions used in their evaluation. In other instances, hazards related to soil physical properties were underestimated. Using computer simulations we demonstrate that some marginal waters considered unusable from state analyses, can in fact be used intermittently without adverse impacts on yield or soil properties.

Water quality criteria related to soil physical properties

A major restriction on use of marginal waters is the large concentrations of sodium relative to calcium and magnesium. A sodic soil has been classified as a soil with an exchangeable sodium percentage above 15, equivalent to an SAR value of the soil water of approximately 13 (where SAR is defined as $\text{Na}/(\text{Ca}+\text{Mg})^{0.5}$, with concentrations expressed in mmol L^{-1}). Earlier water quality criteria (Ayers and Westcot, 1985), considered that the sodicity hazard could be evaluated by consideration of the salinity and SAR of the irrigation water. Utilizing the relationships it has been concluded that it is safe to use waters with SAR at or below SAR 5, although they concluded that irrigation with “very low salinity water (less than $\text{EC}_w = 0.2 \text{ dS/m}$) almost invariably results in water infiltration problems regardless of the SAR”. The water quality criteria of Ayers and Wescot (1985) and others, appear primarily based on relationships developed earlier by McNeal and Colman(1968) and McNeal et al., (1968 and 1970), along with information synthesized from field observations. Additionally flocculation studies by Quirk and Schofield (1954) and others supported the concept that there were threshold values of SAR below which no adverse impacts would be expected. More recent information (Suarez et al. 2006 and Suarez et al. 2008) indicates that the sodium hazards are greater than previously considered and that there is no evidence for a safe threshold value, as any increase in SAR resulted in a decrease in infiltration. The changes in infiltration as related to SAR are shown in Figure 1 and 2 below for the last rain event in loam and clay soil respectively. The differences in infiltration between the $\text{EC } 1 \text{ dS m}^{-1}$ and $\text{EC } 2 \text{ dSm}^{-1}$ waters at various SAR levels were comparable for the both rain events shown as well as for the irrigation events. This suggests

that the effects of EC are not as great as implied by the Ayes and Westcott (1985) stability relationship (Fig 21 in their publication). Also seen by examination of Figure 1 and 2 is that although the loam and clay soil had differences in infiltration, the relative changes in infiltration between the two soils are comparable. These results suggest that soil texture may not be a important factor in terms of predicting changes in relative infiltration rates. In contrast to most of the earlier studies these studies are based on measurements taken over the course of almost one year with periodic wetting and drying cycles that included alternate rain and irrigation cycles. Other studies (Suarez and Gonzalez, 2013, in preparation) indicate that the infiltration rates continue to decrease with time during the season of irrigation events. This indicated that short term changes, such as during a single event or a short term laboratory column experiment, underestimate the sodicity hazard.

The effect of pH has not been generally included in evaluations of impacts of irrigation water on infiltration water. However, it has been demonstrated that pH, independent of SAR, has an important effect on hydraulic conductivity (Suarez et al., 1984). This study examined the pH range of 6-9 and observed adverse effects with increasing pH. The UNSATCHEM model (Suarez and Simunek, 1997) has incorporated those data to include a reduction function on hydraulic properties that considers EC, SAR and pH, although the interactive effects have not been fully evaluated. For high pH waters (above 8.5) acidification may be needed. Based on these newer studies Suarez (2012a) developed new water quality criteria. The relationships shown in Figure 3 consider the increased sensitivity to infiltration losses at lower SAR and account for the adverse effects of elevated pH as well. This Figure provides is to be utilized in environments where there is no appreciable rain. In most irrigated landscapes including Mediterranean type climates, some rainfall does occur and thus the rain hazard must be considered. In the presence of appreciable rain, the hazard is clearly greater at higher SAR; however any SAR above 2 will result in significant loss of infiltration, regardless of the antecedent salinity level in the soil. These criteria represent relative effects; however the relative effects have different impacts, depending on texture. A 20% loss of infiltration on a sandy soil will not likely have an adverse impact on crop production, however a 20% reduction in a clay soil, could be highly adverse. In some regions, such as Imperial Valley the low infiltration rates. Amendment application appear necessary when using many degraded waters.

Again models can be utilized to keep infiltration losses and sodicity and pH effects to a minimum. Result in applications that are at or near the evapotranspiration needs of the crop, thus infiltration losses may be directly related to total water infiltrated and crop yield.

Leaching Recommendations

Leaching recommendations have generally been based on leaching requirements; calculation of the maximum soil salinity that can be tolerated without yield loss. The simple approach taken was to calculate an average rootzone salinity assuming a fixed leaching fraction, steady state conditions and management of the system for maximum yield Ayers and Westcot, 1985).

Average rootzone salinity

The average rootzone salinity calculation does not likely represent the salinity stress experienced by the crop. Plants extract water in a pattern that decreases with depth. The

calculation of salinity in the rootzone is generally calculated based on the input leaching fraction, division of the rootzone into 4 quarters and the assumption that 0.4, 0.3, 0.2 and 0.1 represents the relative water uptake in these intervals. The calculation of an average salinity rather than a water uptake value leads to over-estimation of salt stress and thus overestimation of leaching requirement (Letey et al., 2011).

Fixed leaching fraction

The major simplification in earlier guidelines was that the leaching fraction is a fixed input variable controlled by the irrigator. Thus under high salinity and low water volume inputs, predicted yields are very low. Using a dynamic model that considers the effect of stress on water uptake, some yield is lost but soil salinity is moderated by the reduced plant water uptake. These large differences in leaching fraction, relative yield and salinity between the guidelines and model simulations are dramatically illustrated in Figures 5 and 6 below (Suarez, 2012b). In many instances, especially with water scarcity and low availability, it may be economically feasible to accept some yield loss, utilize marginal waters at lower cost and thus maximize profit to the grower. The leaching requirement needs to be replaced by plant-water soil models and economical evaluation of the predictions.

Boron toxicity

Boron toxicity calculations and boron water quality criteria are currently similar to salt tolerance; calculated from average rootzone boron and steady state. As demonstrated by Goldberg and Suarez (2006) high boron waters can be used for over one year if leaching is minimized (thus minimizing the boron loading) and such waters can be used in a cyclic manner.

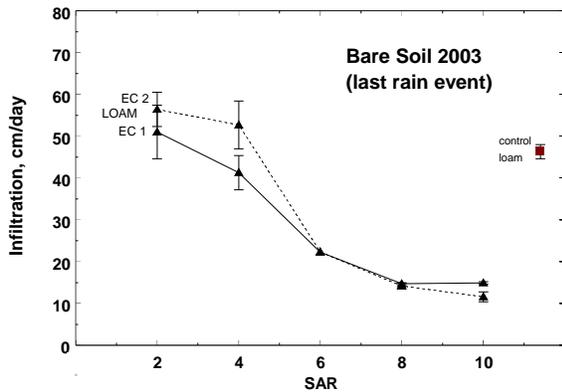


Figure 1

Relationship among infiltration rate, SAR and EC for loam soil during the last rain event (Suarez et al., 2006).

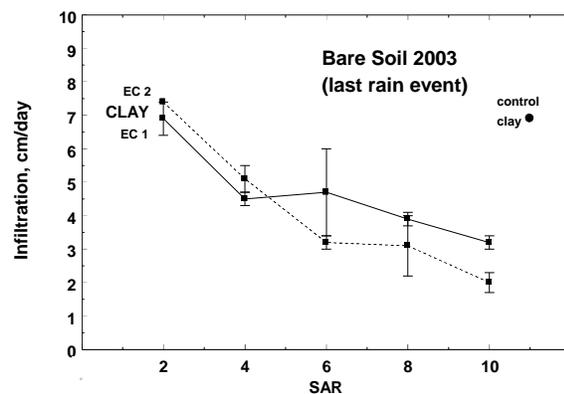


Figure 2

Relationship among infiltration rate, SAR and EC for clay soil during the last rain event (Suarez et al., 2006).

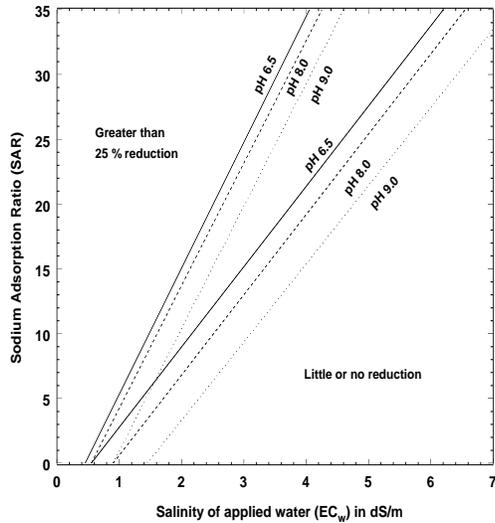


Figure 3
Sodic hazard of irrigation water on water infiltration as related to EC, SAR and pH in the absence of rainfall (Suarez, 2010).

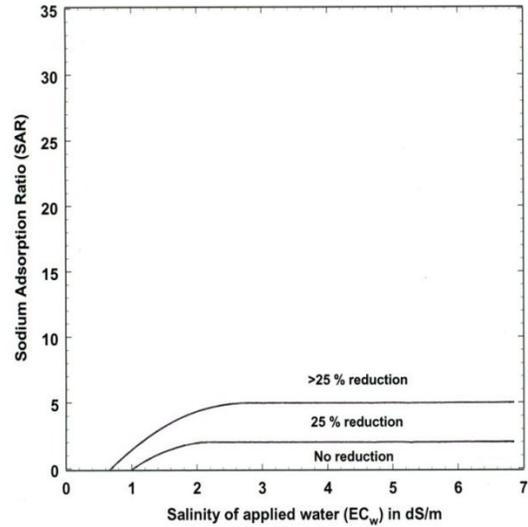


Figure 4
Sodic hazard of irrigation water on water infiltration as related to EC, SAR and pH in the presence of substantial rainfall (Suarez, 2010).

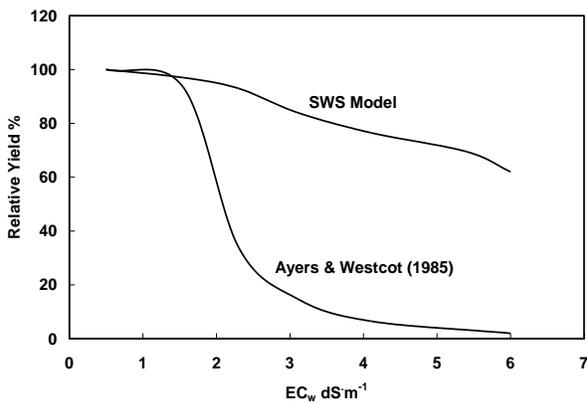


Figure 5
Comparison of SWS model (Suarez et al., 2010) and Ayers and Westcot (1985) predicted crop relative yield as related to irrigation water EC, for a crop with an $h_{50} = -50$ m (-0.5MPa), $ET_p = 200$ cm and 209 cm applied water.

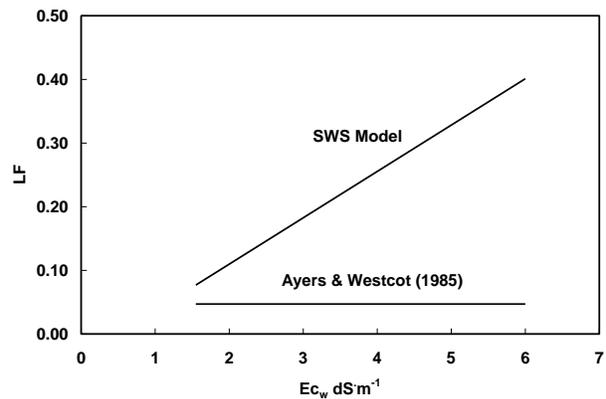


Figure 6
Comparison of SWS model (Suarez et al., 2010) and Ayers and Westcot (1985) predicted leaching fraction as related to irrigation water EC, for a crop with an $h_{50} = -50$ m (-0.5MPa) salt tolerance value, $ET_p = 200$ cm and 209 cm applied water.

Literature Cited

- Ayers, R.S., and D.W. Westcot. 1985. Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29 rev 1. FAO, UN, Rome 174pp.
- Goldberg, S. and D.L. Suarez. 2006. Prediction of anion adsorption and transport in soil systems using the constant capacitance model. In: J. Luetzenkirchen (ed.) Surface Complexation Modeling. Interface Science and Technology Series, Volume 11, Elsevier, Amsterdam. Chapter 18: 491-517.
- Letey, J., G.J. Hoffman, J.W. Hopmans, S.R. Grattan, D.L. Suarez, D.L. Corwin, J.D. Oster, L. Wu and C. Amrhein. 2011. Evaluation of soil salinity leaching requirement guidelines. *Ag. Water Manage.* 98:502-506.
- McNeal, B.L., and N.T. Coleman. 1968. Effect of solution composition on soil hydraulic conductivity. *Soil Sci. Soc. Am. Proc.* 30:308-312.
- McNeal, B.L., W.A. Norwell, and N.T. Coleman. 1968. Effect of solution composition on the swelling of extracted clays. *Soil Sci. Soc. Am. Proc.* 30:313-317.
- McNeal, B.L., J.D. Oster, and J.T. Hatcher. 1970. Calculation of electrical conductivity from solution composition data as an aid to in-situ estimation of soil salinity. *Soil Sci.* 110:405-414.
- Quirk, J.P. and R.K. Schofield. 1955. The effect of electrolyte concentration on soil permeability. *J. Soil Sci.* 6:163-178.
- Suarez, D.L. 2012. Irrigation water quality assessments. In: W.W. Wallender and K.K. Tanji (eds.) *ASCE Manual and Reports on Engineering Practice No. 71 Agricultural Salinity Assessment and Management (2nd Edition)*. ASCE, Reston, VA. Chapter 11 pp:343-370.
- Suarez, D.L. 2012. Modeling transient root zone salinity (SWS Model). In: W.W. Wallender and K.K. Tanji (eds.) *Agricultural Salinity Assessment and Management. ASCE Manual and Reports on Engineering Practice No. 71 (2nd Edition)*. ASCE, Reston, VA. Chapter 28 pp:855-897.
- Suarez, D.L., J.D. Wood, and S.M. Lesch. 2006. Effect of SAR on water infiltration under a sequential rain-irrigation management system. *Agric. Water Manage.* 86:150-164.
- Suarez, D.L., J.D. Wood, and S.M. Lesch. 2008. Impact of sequential applications of rain and irrigation water on infiltration into a cropped soil. *J. Environ. Qual.* 37:S169-S179.
- Suarez, D.L., J.D. Rhoades, R. Lavado, and C.M. Grieve. 1984. Effect of pH on saturated hydraulic conductivity and soil dispersion. *Soil Sci. Soc. Am. J.* 48:50-55.
- Suarez, D.L., and J. Simunek. 1997. UNSATCHEM: Unsaturated water and solute transport model with equilibrium and kinetic chemistry. *Soil Sci. Soc. Am. J.*, 61:1633-1646.
- Suarez, D.L., and P. Taber. 2007. Extract Chem: Numerical software package for estimating changes in solution composition due to changes in soil water content. <http://ars.usda.gov/Services/docs.htm?docid=14567>

Salinity and Drainage Management in the Western San Joaquin Valley— Where are we Today?

Sharon Benes, Department of Plant Science, California State University,
2415 E. San Ramon, Ave., Fresno, CA 93740-8033, Tel: (559) 278-2255, sbenes@csufresno.edu

Introduction

A recent estimate (DWR-NRCS) for the San Joaquin Valley (SJV) is that 1,239,000 acres are affected by salinity (electrical conductivity (EC) > 4 dS/m), 1,819,000 are affected by sodicity (sodium adsorption ratio (SAR) > 13) and 451,000 acres are classified as saline-sodic (EC > 4 dS/m and SAR > 13). Keeping salinity low in the root zone of crops requires proper soil drainage to allow for downward movement of salts in the soil profile, thus salt management is closely tied to drainage management. Studies in 1983 by U.S. Bureau of Reclamation (USBR) estimated that nearly 300,000 acres (42% of land) in the San Luis Unit (Fig. 1) had improper drainage and could benefit from the installation of sub-surface drainage systems to maintain agricultural productivity (Phillips, 2002a). Land retirement (approx. 100,000 acres in Westlands Water District (WWD) and 9,800 acres in the former Broadview Water District) and conversion to micro-irrigation (drip and sprinklers) has reduced their estimate to about 200,000 acres.

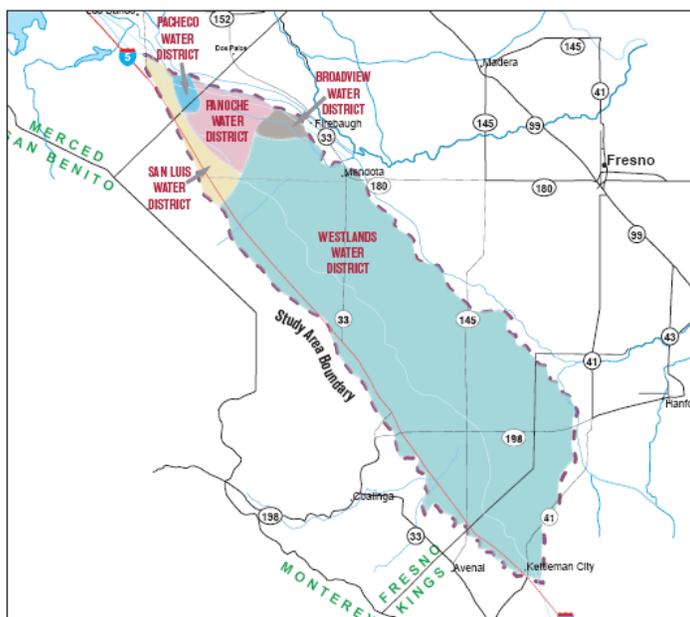


Fig. 1. Map showing water districts that define the San Luis Unit, considered by USBR as the minimum solution area. Areas outside the San Luis Unit may be considered for part of the drainage services as appropriate. http://www.usbr.gov/mp/scca/sld/docs/drainage_need_05-2002.pdf.

As an outcome of multiple lawsuits between affected landowners and the USBR (e.g. Sumner Peck Ranch v. Reclamation decision, 1995 and Appeals Court Decision, 2000), Reclamation has to provide drainage service to the San Luis Unit of the Central Valley Project but it can consider

solutions other than a master drain to the Delta. The San Luis Drain had been the intended drainage service for this area, but selenium-induced poisoning of waterfowl and fish in the Kesterson Reservoir area resulted in closure of the master drain and its collection system in 1985 (Oldfield, 2002).

In the post- San Luis Drain and post-lawsuit era, planning for drainage service is slowly moving forward. Reclamation estimated that drainage flows will be 0.3 to 0.5 acre-ft. water per irrigated acre. The low estimate assumes the best on-farm management practices and would be more accurate in water-short years. Thus, for the 200,000 acres in the San Luis Unit requiring drainage service, approx. 60,000 to 100,000 acre-ft. of drainage water would need to be managed. Although Reclamation has not eliminated Out-of-Valley options (outfall to the Delta or to the Ocean) (Phillips, 2002b), the In-Valley options are considered to be the most feasible in the short term. These include “In-Valley Deposition” options, whereby drainage water would be collected and sent through a process to reduce its volume prior to final disposal (or harvesting) of the salts. Volume reduction systems could include:

- **Treatment options** such as reverse osmosis (RO) in which the final brine would require disposal and the product water would be available for use. Salt harvesting from the brine could generate revenue to off-set the costs of the RO system. Other treatment systems for salt and/or selenium removal are also being explored.
- **Solar ponds** with enhanced evaporation systems, e.g. special nozzles to atomize the water, to minimize standing water.
- **Agricultural re-use:** irrigation with saline drainage water to reduce its volume through crop evapotranspiration (ET). Forage and/or biofuel crops are good candidates due to lower crop maintenance requirements. Treatment or evaporation of the concentrated drain water would likely follow.

Income generation is key to finding sustainable systems that will allow drainage service to be implemented and maintained. The major drawback of treatment systems, especially those not paired with agricultural re-use to first reduce drainage volumes, is the cost of the treatment. Water treatment to remove salt (and/or selenium) is very energy intensive which would keep system maintenance costs high. Working with a more concentrated effluent is usually more efficient for treatment, as well as for solar evaporation and salt harvesting. *New Sky Energy* (www.newskyenergy.com) has promoted a process whereby salts could be harvested from agricultural wastewaters or brines and converted to higher value products, e.g. sulfuric acid from Na_2SO_4 , hydrochloric acid from NaCl , along with bases such as NaOH and carbonates such as baking soda and soda ash from the sodium fraction. Soda ash is used in glass-making and baking soda is used for baking and as a feed supplement for dairy cattle to buffer the rumen.

Regardless of the treatment or disposal systems utilized, most believe that agricultural re-use will be an important part of salinity and drainage management in the western SJV. Utilization of saline drainage water for irrigation would expand the water supply for irrigation and many forage and biofuel crops have high levels of salt tolerance (Benes et al., 2010; Suyama et al., 2007). Agricultural re-use also has the benefit of drawing from agricultural expertise in the local area and it would generate revenue for the treatment and/or disposal systems needed for the final

effluent. Drawbacks include the potential for soil degradation due to the saline irrigation. Leaching could restore the profile, but the presence of high levels of boron in some of the western SJV drainage waters would increase the water requirement for reclaiming the profile. Having dedicated lands for re-use, which may never be restored to their original productivity, is one option.

The San Joaquin River Improvement Project (SJRIP) operated by Panoche Drainage District (PDD) (Firebaugh, western Fresno County) since 2001 is the best example of successful regional management of saline drainage water. The project is part of the Grasslands Bypass Project which uses a small portion of the former San Luis Drain to re-direct drainage water from wetland water supply channels. The conditions placed on discharge to the San Joaquin River are that tiered reductions in selenium (Se) loading must be met and eventually the system must move to zero discharge. The most successful component of the SJRIP is the reuse area located on 6,000 acres of marginal land which receives agricultural drainage water from the surrounding 97,000 acres of productive land. Currently, 4,700 acres are in production of which 3,700 acres are dedicated to the production of 'Jose' tall wheatgrass (*Thinopyron ponticum*) hay, 295 acres of alfalfa hay, a small area of Seashore Paspalum (*Paspalum vaginatum*), a highly salt tolerant turfgrass, and 20 acres of pistachios. The tall wheatgrass has yielded 6 tons/acre on the average and has been well-received by local dairies. Thus far the forage crop has been grown without fertilizer or pesticide application. PDD has been able to sell all of the hay produced and will be expanding its tall wheatgrass acreage.

Tall wheatgrass is a perennial, cool season bunchgrass which is highly salt tolerant. At Red Rock Ranch (Five Points, western Fresno County) it was irrigated with drainage water of higher salinity (8-10 dS/m EC_w) for 8 years and yields of 3.2 tons/acre were achieved, even when soil salinities reached 19 dS/m EC_e (Suyama et al., 2007). Yields of 6 ton/acre were reported by the grower in earlier years when soil salinity was lower. Similar to the tall wheatgrass cultivation in the SJRIP, no fertilizer was applied to the forages fields at Red Rock Ranch as the agricultural drain water applied to these fields had very high concentrations of nitrate (44 to 88 ppm NO₃-N).

The re-use area in the SJRIP provides immediate drainage relief while various salt and selenium removal technologies are being tested. The average drainage water concentration applied to the tall wheatgrass is 5.7 dS/m (concentration of 5 tons of salt/acre-ft. water). The SJRIP re-use design estimated that 27% would move into the tile drainage. Intercepted drain water averages 21.4 dS/m (20 tons of salt/acre-ft.). The primary function of the forage production is to reduce the volume of drainage (approx. 73% water removal via crop ET and surface evaporation) and concentrate salts for eventual treatment or evaporation of the concentrated effluent. Even with the high ash content of the forage (8-10%), uptake of salt by the forage is only 1% of the total salt load moving through the system (PDD, 2010). Removal of selenium by the forage is likely to be more significant because Se concentrations in agricultural drainage water and soils are much lower than are salt concentrations. Thus far the SJRIP has reduced salt and selenium loading into the San Joaquin River. Reducing agricultural drainage to the river also reduces nutrient loading and in turn, could lessen dissolved oxygen problems downstream in the river (Falaschi and McGahan, 2001).

The SJRIP has a monitoring program to measure selenium levels in bird eggs (black-necked stilt, American avocet, killdeer, and red-winged blackbird). Se levels were also monitored in vegetation, small mammals and a coyote to estimate potential Se exposure to the San Joaquin Kit Fox, an endangered species. Mitigation efforts to reduce Se exposure to wildlife include netting or closing certain irrigation and drainage ditches during nesting season, hazing near the ditches, providing compensation breeding habitat and proper water management in the re-use fields to avoid standing water, along with a contingency plan for flooded field conditions (H.T. Harvey & Associates, 2011).

Not all water districts are inclined to enter into farming, but PDD has developed a successful system. This fall Tulare Lake Drainage District (TLDD) established test plantings of 25 acres each of 'Common' and 'Giant' Bermudagrass. Their objective is to generate a profit, or to at least offset the cost of the farming operation which they estimate to be more expensive than the more inert operation of their evaporation basins (Gary Rose, personal communication). Lost Hills Water District in Kern County has also developed drainage management plans involving agricultural re-use and salt disposal. On-farm examples of integrated drainage management (IFDM) include Red Rock Ranch and Andrews Ag in southern Kern County. At Andrews Ag, halophytic plants native to the area (saltgrass- *Distichlis spicata* and iodine bush- *Allenrolfea occidentalis*) are used to consume saline drainage water prior to its discharge into solar evaporators.

As reflected by the examples above, salinity and drainage management strategies will be combined in different ways to suit the surrounding area. The timeframe for drainage implementation in the San Luis Unit, as required of USBR by the federal court rulings, is difficult to determine. Not only the cost of the treatment and disposal facilities proposed, but of the subsurface drainage systems (on-farm and collector system) for the 200,000 acre service area will be far upwards of 100 million dollars. Several regional facilities rather than one large centralized facility are envisioned. Studies are underway to identify the proper locations for these facilities, taking into account soil type and drainage characteristics. Payment for the on-farm cost of subsurface drainage installation (approx. 1,000 to 1,200 per acre) will need to be negotiated between USBR and the landowners.

Literature Cited

1. Benes S.E., Suyama H., Grattan S.R., Robinson P., Juchem S.O. and Adhikari D.D. (2010). *Forage Production under Saline Irrigation*. California Plant and Soil Conference (state-wide meeting, California Chapter of American Society of Agronomy). Feb. 2, 2010, Tulare, CA. pp. 98-104.
2. Department of Water Resources (DWR) and U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic Database (SSURGO). <http://soils.usda.gov/survey/geography/ssurgo/>.
3. Falaschi D., McGahan J. (2001). San Joaquin River Water Quality Improvement Project- Phase II Implementation. <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=5656>.

4. H.T. Harvey & Associates (2011). San Joaquin River Water Quality Improvement Project, 2011 Wildlife Monitoring Report. <http://www.sfei.org/gbp/sjrip>
5. Oldfield J. E. (2002). A brief history of selenium research: from alkali disease to prostate cancer (from poison to prevention). Journal of Animal Science. <http://www.asas.org/Bios/Oldfieldhist.pdf>
6. Panoche Drainage District (PDD) (2010). San Joaquin River Improvement Project. Aug. 1, 2010. 4 pp. Tel: (209) 364-6136.
7. Phillips J. (2002a). Drainage Need. San Luis Drainage Feature Re-evaluation series. United States Bureau of Reclamation, South-Central California Area Office (SCCAO). <http://www.usbr.gov/mp/sccao/sld/overview.html>.
8. Phillips J. (2002b). Drainage Service Options. San Luis Drainage Feature Re-evaluation series. United States Bureau of Reclamation, South-Central California Area Office (SCCAO). <http://www.usbr.gov/mp/sccao/sld/overview.html>.
9. Suyama H., Benes S.E., Robinson P.H., Getachew G., Grattan S.R., and Grieve C.M. (2007). Biomass yield and nutritional quality of forage species under long-term irrigation with saline-sodic drainage water: field evaluation. Anim. Feed Sci. Technol. 135:329-345.



American Society of Agronomy

California Chapter

2013 Poster Abstracts

**Poster Chair:
Rodrigo Krugner**

POSTER SUBMISSION: STUDENT

Title of Paper: **Se-enriched Tall Wheatgrass Hay as a Substitute for Sodium Selenite in the Diets of Dairy Cattle**

Authors: Grace Cun^{1,2}, P.H. Robinson² and Sharon Benes¹

Contact Name: Grace Cun

Affiliations: ¹Department of Plant Science, California State University, Fresno and ²Department of Animal Science, University of California, Davis

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

Telephone: 951-941-6583

Fax: 559-278-7413

E-mail: gracecun@gmail.com

ABSTRACT:

Tall wheatgrass (TWG) is a Se-accumulating, salt tolerant forage suitable for cropping systems which re-use agricultural drainage and tail water. Utilization of TWG as a Se supplement for dairy cattle could reduce the importation of 'new' Se into the San Joaquin Valley (SJV) of California in the form of sodium selenite (NaSe), a common dietary supplement in the eastern SJV where Se levels are low in soils and forages. Our study utilized Se-enriched (~5 ppm of dry matter (DM)) TWG hay as a Se source for lactating dairy cows and determined Se accumulation patterns in blood, urine and feces to determine its bioavailability. Three pens of ~310 cows each were fed an identical total mixed ration (TMR) in a Latin Square design, except that the supplemental Se source differed (i.e., none; TWG; sodium selenite (NaSe)). The chemical composition of the diets was the same, except for Se which was increased ($P < 0.0001$) in the TWG and NaSe diets (0.53 and 0.65 mg/kg DM) as compared to 0.35 mg/kg DM in the control diet. Feeding Se-enriched TWG increased blood Se by 6.4% over the control; whereas NaSe increased it by only 4.8%, suggesting higher bioavailability for Se in TWG hay vs. NaSe. In contrast, the amount of dietary Se that was digested increased from 47 to 58% with NaSe, but with TWG supplementation there was no increase over the control, suggesting lower bioavailability for TWG as compared to NaSe. Se outputs in the urine did not differ among treatments, thus the metabolizability of Se from NaSe appears to be higher than that from TWG. Analysis of total Se levels in the milk will provide additional information regarding the potential of Se-enriched TWG hay as a value-added product for forage producers in the western SJV.

POSTER SUBMISSION: STUDENT

Title of Paper: **Comparison of Salt Tolerant Alfalfa (*Medicago sativa*) Genotypes.**

Phase I: Seed Germination Response

Authors: Inderjot Chahal¹, Sharon Benes¹, Daniel Putnam² and Stephen Grattan³

Contact Name: Sharon Benes

Affiliations: ¹Department of Plant Science, California State University, Fresno; ²Department of Plant Sciences and ³Department of Land, Air and Water Resources, University of California, Davis

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

Telephone: 559-278-2255

Fax: 559-278-7413

E-mail: sbenes@csufresno.edu

ABSTRACT:

The need for salt-tolerant alfalfa varieties is increasing in the Central Valley of California because of water shortages and the increased need to utilize saline waters for irrigation. Being a tetraploid with great genetic diversity, there is much potential for alfalfa variety improvement through breeding. The objectives of this study are to compare the relative salt tolerance of new alfalfa genotypes in terms of their seed germination, dry matter yield and mineral nutrient content under saline conditions. The study consists of three phases in which saline stress is imposed at seed germination, emergence through early seedling growth, or as mature plants; but only Phase I data will be presented. In Phase I, twenty salt tolerant varieties were tested for germination at seven salinity levels ranging from 0.5 to 24 dS/m EC. Seeds were placed in petri dishes on germination paper wetted with the saline solutions and germination percentages were recorded after 3 and 7 days. EC_{w50} and EC_{w90} values (salinities corresponding to 50 and 90% germination, respectively) were calculated using the Day 7 data. The best-performing varieties based on the EC_{w50} were CW8028 (Cal West), Ameristand 901SQ (Forage Genetics) and AZGERM Salt II (USDA-GRIN) with values of 12 to 13 dS/m. However, based on EC_{w90} values (less saline condition), the top-performing varieties were AZGERM Salt II, Hybriforce800 (Dairyland) and CW8028 with values of 4.0 to 6.6 dS/m. Varieties demonstrated different types of salinity tolerance. For example, Hybriforce 800 had a relatively high EC_{w90} (5.88 dS/m) suggesting a high threshold for seed germination decline, but its EC_{w50} was relatively low (7.65 dS/m), indicating that its germination potential decreases rapidly as salinity increases beyond the threshold.

POSTER SUBMISSION: STUDENT

Title of Paper: **Crop Growth, Lint Yield, and Pest Population Dynamics in Cotton Under Conservation Cropping Systems**

Authors: Joy Hollingsworth¹, Anil Shrestha¹, Jeff Mitchell², Dan Munk³, Bruce Roberts¹

Contact Name: Anil Shrestha

Affiliation: California State University, Fresno, CA¹; University of California, Davis, CA²,
University of California, Cooperative Extension, Fresno, CA³.

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

Telephone: 559-278-5784

Fax: 559-278-7413

E-mail: ashrestha@csufresno.edu

ABSTRACT:

Conservation cropping systems are being developed for cotton that has traditionally been grown on raised beds with several soil-disturbing tillage passes in the San Joaquin Valley (SJV) of California. These beds are irrigated by flood, furrow, or sprinkler systems and have limited options for crop rotation. Overhead (OH) and subsurface drip irrigation (SDI) systems are two water conserving techniques being tested in combination with reduced tillage and strategic crop rotations in the SJV. However, crop growth, yield, soil temperature, moisture, and pest population dynamics in these new cropping systems have not been documented. Therefore, a study was initiated in 2010 to compare these parameters in a conservation tillage silage wheat-cotton - silage wheat-cotton rotation with OH or SDI systems. The cotton was a Roundup Ready Acala variety. The experimental design was a randomized complete block with irrigation systems as treatments. The use of OH or SDI allowed flat-planting of cotton and made crop rotation feasible. Results in 2011 showed that crop growth parameters and yield were generally similar in the OH and SDI systems. However, the top 15 cm of the soil in the OH plots was wetter and cooler than the SDI plots at most sampling dates during the growing season. The SDI plots had a greater spider mite (*Tetranychus* sp.) population but lower weed densities than the OH plots.

POSTER SUBMISSION: STUDENT

Title of Paper: **Seasonal Variation in the Phenolic Profile of a Peach x Almond Hybrid F2 Generation**

Authors: Max Henning¹, John Constable¹, Chris Wallis², Craig Ledbetter²

Contact Name: John Constable

Affiliations: California State University, Fresno, CA¹, USDA-Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, Parlier, CA².

Address: 5241 N. Maple Fresno, CA 93740

Telephone: 559-278-4240

E-mail: jconstable@csufresno.edu

ABSTRACT:

In order to create better rootstocks of *Prunus* for California growers, a cross was made between wild almond species, *Prunus webbi* and a commercial peach variety 'Harrow blood'. Subsequently, a single F1 individual was selfed to produce an F2 population in which rootstock characteristics could be assessed. A linked project was initiated in 2012 to evaluate the foliar phenolic profile of the P, F1 and F2 generations. This study is testing the hypothesis that (i) both phenolic concentration and content will differ between individuals in the F2 population and (ii) differences in phenolic composition correlates with overall tree vigor and susceptibility to infection from powdery mildew fungi. The F2 study population consists of 30 trees divided into three caliper size groups, large (34.3 to 40.5 mm), medium (15.3 to 16.6 mm) and small (9.5 to 10.6 mm), along with the F1 and parental *P. webbii* and *P. persica* 'Harrow Blood'. Leaves of all individuals were sampled weekly from March 2012 to September 2012. Sampling was designed to highlight the developmental and seasonal variation in phenolic concentration and content. Phenolic profiles are being evaluated using High Performance Liquid Chromatography. Secondary metabolites including phenolics are necessary for plant growth and defense. Plants with greater phenolic content are less susceptible to abiotic and biotic stressors and thus have more vigorous growth. This study will provide information regarding the role of increased phenolic content and overall plant vigor.

POSTER SUBMISSION: STUDENT

Title of Paper: **Preliminary Investigation into the Effects of Endophytes on Tomato Growth**

Authors: TariLee Frigulti^{1,2}, Greg Philips² and Jianchi C. Chen²

Contact Name: TariLee Frigulti

Affiliation: California State University, Fresno, CA¹, USDA-Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, Parlier, CA².

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

Telephone: 559-278-2861

E-mail: tleef@mail.fresnostate.edu

ABSTRACT:

Bacterial endophytes have the capacity to synthesize hormones and metabolites that can impact plant growth and health. It is important to study the effects of endophytes and how they may influence plant growth and development. In this experiment, tomato (*Solanum lycopersicum* L.) plants were grown from seed and from apical rooted cuttings. At approximately six weeks after sowing, the plants were inoculated with either *Stenotrophomonas* sp., *Acinetobacter* sp. or the control phosphate-buffered saline. Two weeks later, plant growth rates were statistically analyzed to examine if there was any effect of the different treatments. ANOVA indicated that there were no significant effect on the growth rate of the inoculated plants grown from seeds ($P=0.87$), whereas for the plants grown from cuttings the effect of the inoculants was significant ($P=0.095$). ANCOVA statistic indicated that initial plant height had a significant covariate effect ($P\leq 0.001$), which implies that it is essential to consider the initial plant height, and the phenological stage, in any study investigating the impact of endophytes on the growth rate of tomatoes. This information can lead to innovative applications of using endophytes to help prevent or reduce plant stress.

POSTER SUBMISSION: STUDENT

Title of Paper: **Developing Crop Coefficients for Processing Tomatoes under Subsurface Drip Irrigation**

Authors: Bardia Dehghanmanshadi, Florence Cassel Sharma, and Dave Goorahoo

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:

Irrigated agriculture accounts for a major share of consumptive water use in the United States. However, with the increasing demand for water due to population growth and environmental directives as well as uncertainty linked with climate change, water allocation to the agriculture sector may be declining in the future. Therefore, improving on-farm water use efficiency and optimizing estimation of crop water requirements will be critical to the sustainability of irrigated agriculture. Crop water requirements are determined to effectively schedule irrigation and are usually estimated by multiplying reference evapotranspiration (ET_o) with coefficients specific to a particular crop (K_c). Coefficients have been compiled for many crops but were developed under very specific management practices that do not always reflect current cultural and irrigation practices in California. Additionally, K_c are not available for many horticultural crops. Thus, the objective of our study was to develop new K_c for processing tomatoes grown under sub-surface drip irrigation. The K_c were obtained through lysimeter studies conducted during two growing seasons in Five Points, CA. Daily measurements of crop ET and ET_o were collected to derive these K_c . Weekly measurements of crop ground cover were also performed to derive relationships between K_c and fractional cover. The K_c reached a maximum value of 1.2 at mid-season and started declining about 20 days later. Data indicated that coefficients obtained at peak season were relatively higher than those generally reported for tomatoes. Results also showed good correlation between fractional cover and K_c ($r^2 = 0.91$). The K_c increased curve linearly until canopy reached about 75% of fractional cover. Such findings are important to schedule effective irrigation cycles and optimize the use of water resources.

POSTER SUBMISSION: STUDENT

Title of Paper: **Stem-Water Potential Reading Variability in Olive (*Olea europaea*)**

Authors: Luke K. Milliron, Bill Krueger, and Richard Rosecrance

Contact Name: Luke K. Milliron

Affiliation: College of Agriculture, California State University, Chico 95926, and University of California Cooperative Extension, Glenn County, Orland 95963

Address: 1186 Filbert Ave. Chico, CA 95926

Telephone: 530-828-9666

Fax: 530-865-1107 (UCCE Glenn County)

E-mail: lukesb13@yahoo.com

ABSTRACT:

In the face of growing water insecurity, California farmers have embraced irrigation management technologies which help ensure a greater ‘crop per drop’. Stem-water potential (Ψ_{stem}) is a plant based irrigation management tool that measures water stress. Previous research has established numerous technician measurement protocols to minimize variability in almond, walnut and prune water stress readings; these protocols have been adopted in olive with only anecdotal evidence of their validity. The objective of this study is to explore variability in Ψ_{stem} readings in olive (*Olea europaea* cv. ‘Arbequina’ and ‘Manzanillo’). Potential variability arising from crop load, the presence of olive knot, the location of the sampled shoot on the tree, shoot samples containing fruit, a two minute post excision interval before placement in the pressure chamber, the length of the stem protuberant from the pressure chamber, re-pressurizing a bagged shoot, and examining differences between technicians are all investigated. Readings are principally taken from several replicates on four to five trees in a single fully irrigated row. Data sets are analyzed using ANOVA as a single factor randomized block design (RBD - 1 factor), blocking by tree. In the overall analysis of all investigations, the variability tested was insignificant (p-value > .05). An exception to the overall findings occurred in two of three investigations regarding the location of the sampled shoot on the tree, as well as the first of nine trials comparing readings between two operators. These results suggest a robustness of Ψ_{stem} readings, despite variance in tree physiology and operator technique. The exceptions noted are also consistent with literature finding bag placement and operator as potentially significant sources of variation.

POSTER SUBMISSION: STUDENT

Title of Paper: **Nitrous Oxide Emissions from Cotton Following Fertilization and Irrigation**

Authors: Navreet K Mahal, Dave Goorahoo, Florence Cassel Sharma, Bruce Roberts, Prasad Yadavali and Gabriela Mello

Contact Name: Navreet K Mahal

Affiliation: Plant Science Department, California State University, Fresno

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

Telephone: 559-495-8148

Fax: 559-278-7413

E-mail: navreetmahal@mail.fresnostate.edu

ABSTRACT:

Of the three biogenic greenhouse gases (GHGs) (i.e., carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O)), N₂O is considered to be the most potent. It has been estimated that in California, agricultural soils accounts for 64% of the total N₂O emissions. California's San Joaquin Valley (SJV) is among the major producers of cotton in the United States. The overall goal of this study was to determine detailed time series of N₂O fluxes at crucial management events, such as irrigation and fertilization, for two cotton crops in the Central Valley of California. For Site I, the objective was to determine N₂O fluxes for cotton fertilized with Urea Ammonium Nitrate (UAN 32) combined with a nitrification and urease inhibitor. Flux chamber measurements, using an Environmental Protection Agency (EPA) approved methodology, were conducted on beds at four times during the summer. For the Site II, the objective was to determine N₂O fluxes in furrows and beds for cotton fertilized with UAN 32. The flux chamber measurements were conducted to collect air samples which were ultimately analyzed using a Gas Chromatograph (G.C.). At Site I, N₂O emissions were influenced by Nitrogen (N) fertilizer rates and irrigation events. For example, N₂O fluxes ranged from less than 10 to 40 ug N/m²/h for plots receiving 50 to 100 lbs N/acre, respectively. After an irrigation event, these fluxes increased to 20 to 80 ug N/m²/h. Generally, the inhibitor reduced N₂O fluxes by as much as 50%. For Site II, N₂O fluxes from beds averaged 128 μg N/m²/d, which was approximately 31% more than that detected from the furrows. Future work will include the calibration of the Denitrification-Decomposition Model (DNDC) for quantifying N₂O emissions from cotton cropping systems in the SJV.

POSTER SUBMISSION: STUDENT

Title of Paper: **Glutathione Levels in Tomatoes Subjected to AirJection® Irrigation**

Authors: Jayakrishna Ichapurapu, Dave Goorahoo, Joy Goto and Florence Cassel Sharma

Contact Name: Dave Goorahoo (Adviser)

Affiliation: Plant Science Department, California State University, Fresno

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

Telephone: 559-278 8448

Fax: 559-278-7413

E-mail: dgooraho@csufresno.edu

ABSTRACT:

Oxidative stress is one of the most important abiotic stress factors that can adversely affect plant growth and yield. Glutathione (Glu), an important plant antioxidant is considered to play a key role in the control of oxidative stress. The levels of GLU, along with its reduced (GSH) and oxidized (GSSG) forms, and the ratio of GSH: GSSG are useful indicators of oxidative stress in a plant. Generally, lower ratios indicate a relatively lower level of oxidative stress. AirJection® Irrigation, which is basically the application of aerated water into the root zone via a subsurface drip irrigation system, may potentially alleviate oxidative stress to plants. Hence, the primary objective of this study was to test the hypothesis that the injection of a mixture of air and water directly into the root zone will reduce the oxidative stress in tomato plants as evident by the relative levels of GSH, GSSG and total Glu in leaf and fruit samples. The study was conducted on clay soils in Firebaugh, CA as part of an ongoing project aimed at evaluating the impact of AirJection® irrigation on crop yield and soil salinity. Leaf and fruit samples were collected at the harvest growth stage, equivalent to 100 days after transplant (DAT) from tomato beds treated with water only (control) and those beds treated with AirJection® irrigation. The GSH, GSSG and total Glu levels were quantified using Biovision Glutathion™ assay kit. Both the fruit and leaf samples from the AirJection® beds had relatively lower levels of GLU, GSSG and GSH thereby implying a lower oxidative stress level in comparison to plants grown on beds treated with water only. The ratio of GSH to GSSG was also lower in plants subjected to AirJection® irrigation compared to those in the control plots (water only).

POSTER SUBMISSION: STUDENT

Title of Paper: Effects of Fertilizer and Irrigation on Nitrate and Chlorophyll Contents in Tomato Leaves

Authors: Janet Robles, Navreet Mahal, Prasad Yadavali, Dave Goorahoo and Florence Cassel Sharma

Contact Name: Dave Goorahoo (Adviser)

Affiliation: Plant Science Department, California State University, Fresno

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

Telephone: 559-278 8448

Fax: 559-278-7413

E-mail: dgooraho@csufresno.edu

ABSTRACT:

Tomato is one of the most important vegetables grown in the United States. Due to continuous rise in the cost of fertilizers and irrigation water crisis, there is a need to continuously find ways for efficient use of fertilizers and irrigation water, without affecting the quality and quantity of the tomatoes. This study was part of larger research project aimed at evaluating current approaches utilizing products, such as soil surfactants, potentially enhance water and nutrient uptake by plants, and thereby optimize overall crop productivity. The specific was to determine effect of fertilizer and irrigation rates on the nitrate concentrations and chlorophyll contents of tomato leaves during different growth stages. The study was conducted on a sandy loam soil, as a split-split plot experiment, with irrigation (high, medium and low) as the main factor, and surfactant (with and without) and fertilizer rates (100, 150 and 200 lbs N/acre) as secondary factors. Leaf petioles were analyzed for nitrate concentrations at 1" diameter of fruit stage (first ripe stage) and at harvest, with weekly chlorophyll contents in leaves determined using a SPAD 502 Plus Chlorophyll Meter. At first ripe stage, fertilizer rates had a significant effect ($P = 0.02$) on leaf tissue nitrate content, with rates of 150 and 200 lbs N/acre resulting in the highest levels for all the irrigation and surfactant treatments. At harvest, mean petiole nitrate level was highest in plants receiving 200 lbs N/acre, and there was also was an interaction effect of the three treatments at the $P=0.10$ significance level. Overall, there was a slight decrease in the chlorophyll contents in leaves as the tomatoes progressed from immature green stage to harvest.

POSTER SUBMISSION: STUDENT

Title of Paper: **Comparison of Organic and UAN-32 Fertilization on Bok Choy Yield and Soil Properties**

Authors: Meiyue Wang, Touyee Thao* and Dave Goorahoo Ph.D

Contact Name: Dave Goorahoo (Adviser); *Touyee Thao (Presenting author)

Affiliation: Plant Science Department, California State University, Fresno

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

Telephone: 559-278 8448

Fax: 559-278-7413

E-mail: dgooraho@csufresno.edu (adviser); touyee1@mail.fresnostate.edu (presenting author)

ABSTRACT:

California leads the nation in agricultural production with over three hundred crops produced annually. Among these crops are specialty vegetables such as Bok Choy, Daikon, Bitter Melons and Nappa cabbage which are commonly grown by the South East Asian Community (SEAC). With the need to increase production and remain competitive in the local, national and global markets, these SEAC growers are often turning to excessive agro-chemical applications to ensure high yields and early maturity. These growers are also faced with environmental regulations, particularly linked to soil salinity and nitrate contamination of water resources. The overall goal of our current study is to evaluate if slow release nitrogen (N) fertilizer formulations, applied to various South East Asian (SEA) vegetables commonly grown in California. In this phase, the objective was to evaluate the effects of an organic (ORG12) and inorganic (UAN32) fertilizers on the (i) yield of Bok Choy, and (ii) soil pH and electrical conductivity (EC). A sandy loam soil was used in a greenhouse (pot) study. Bok Choy seeds were planted in early November 2011 (0 DAT). The experimental setup was a completely randomized block design (CRBD) comprising of 4 blocks of 6 pots each (2 fertilizers x 3 rates). Fertilizer rates were 30, 90 and 150 lbs N/ac. Irrigation was based on the crop- evapo transpiration (ET_c) requirements, determined primarily by the soil moisture levels in the top four inches in the pots, and visual observation of either leaf turgidity or wilting. At harvest, there were significant differences in yield due to both fertilizer type ($P= 0.03$) and application rates ($P= 0.09$) with the mean weight of Bok Choy heads being 275 ± 16 g and 219 ± 20 g for the plants treated with the UAN32 and ORG12, respectively. However, there was no significant difference in soil pH and EC as a result of the fertilizer treatments. These findings are encouraging as SEAC growers seek out innovative fertilization techniques for enhancing vegetable production.

Funding for this project was provided by CSU 2011-2012 Undergraduate Research Grants administered by Office of Undergraduate Studies.

POSTER SUBMISSION: STUDENT

Title of Paper: **Effect of Irrigation and Nitrogen Rates on Weed Competition in Fresh Market Tomatoes**

Authors: Jorge Angeles, Anil Shrestha and Dave Goorahoo

Contact Name: Anil Shrestha (Adviser)

Affiliation: Plant Science Department, California State University, Fresno

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

Telephone: 559-278 5784

Fax: 559-278-7413

E-mail: ashrestha@csufresno.edu

Water shortages and nitrate leaching is leading to the development of resource-efficient cropping systems in California. However, a concern with reducing these inputs is increased competition from weeds. A study was conducted to evaluate the effect of 3 levels of irrigation [100%, 80%, and 60% of evapotranspiration (ET_c)], 3 rates of N (100, 150, and 200 lbs/ac), and soil-surfactant on weed densities, biomass, and tomato growth. Tomato seedlings were transplanted in May on 60-inch beds. The experimental design was a split-split plot with irrigation, surfactant, and N rates as the factors. The irrigation system was subsurface drip. Fertilizer was applied through the drip tape. Surfactant was applied at 1 gal/acre + 2 gallons of water. Similar amount of water was also applied to the no-surfactant plots. Weed densities were estimated on June 7 and 21, and on August 21. Weed biomass was estimated on July 19. Tomato plant height in each plot was also measured. Weed densities were similar in all the treatments on June 7; but on June 21 and August 10, densities were greatest in the 100% ET_c plots. Surfactant and N had no effect on weed densities. Weed biomass was greatest in the 60% ET_c plots and in the 200 lbs/ac N plots. Surfactant had no effect on weed biomass. At harvest, tomato plants were tallest in the 100% ET_c plots. Nitrogen and surfactant had no effect on tomato height. In conclusion, reduction in irrigation reduced weed densities but increased weed biomass. Tomato plants were shorter when irrigation was reduced. This may mean that the weeds were more competitive than the crop at the lowest irrigation level. However, weed biomass was reduced by lower N rates. Therefore, an adequate balance between irrigation and N will be required to reduce weed competition while developing resource-efficient cropping systems.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: Effect of High Frequency Surface and Subsurface Drip Irrigations on N₂O Emissions in Orchards

Authors: Aileen Hendratna¹, Suduan Gao¹, and Claude Phene²

Contact Name: Aileen Hendratna

Affiliation: ¹USDA-ARS, Water Management Research, Parlier, CA, ²SDI+ Consultant, Clovis, CA.

Address: 9611 S. Riverbend Ave, Parlier, CA 93648

Telephone: 559-596-2871

E-mail: aileen.hendratna@ars.usda.gov

ABSTRACT:

Fertilized agricultural soil is a source for greenhouse gas nitrous oxide (N₂O) emissions. A sustainable agricultural practice needs to consider minimizing N₂O emissions while increasing N use efficiency and maintaining crop economic yield and quality. In order to develop a sustainable crop production system, subsurface drip irrigation (SDI) was tested for efficient water and N use in a pomegranate orchard in Parlier, CA in comparison to surface drip irrigation (DI). The N fertilizers were applied in the forms of N-pHuric (urea, sulphuric acid) and AN-20 (ammonium nitrate 20% N). The objective of this research is to determine N₂O emissions affected by SDI and DI as well as fertilizer application rates. The static flux chamber method was used to measure N₂O emission flux from research plots using SDI and DI with three N application rates. The data show that the SDI system generated much lower N₂O emissions than DI especially at higher N application rates. A positive linear correlation between the N₂O emission flux and N₂O concentration in soil-gas phase was identified. Further understanding of N transformations and soil conditions related to N₂O emission and irrigation systems are needed to develop good management practices for efficient N use.

POSTER SUBMISSION: PROFESSIONAL

Title of Paper: Nitrogen Impacts Bell Pepper Yield but Not Postharvest Quality

Authors: Michelle Le Strange¹ and Marita Cantwell²

Contact Name: Michelle Le Strange, University of California Cooperative Extension (UCCE).

Affiliation: ¹UCCE Farm Advisor, Tulare and Kings Counties; ²UCCE Postharvest Specialist, Plant Sciences Department, University of California at Davis.

Address: 4437-B S. Laspina Street, Tulare, CA 93274. USA.

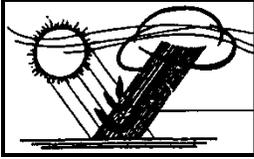
Telephone: 559-684-3320.

Fax: 559-685-3319.

E-mail: mlestrange@ucdavis.edu

Bell peppers are grown in California for fresh and processing markets and many growers apply liquid nitrogen fertilizers through a drip irrigation system. Nitrogen best management practices have not been updated for many years, nor has there been a recent study investigating the relationship between nitrogen fertilizer and pepper quality at harvest, when grown under drip irrigation. Three field studies (2009-11 at UC WSREC) investigated 5 rates of nitrogen fertilizer (60 to 375 lbs/acre as CAN 17) on yield and postharvest quality of peppers grown under subsurface drip and irrigated on an evapotranspiration schedule. Whole leaf samples were collected during the growing season and analyzed for N content. The field was picked twice for yield, quality attributes, and postharvest evaluations. Pepper quality parameters include fruit weight, color, firmness, bruise susceptibility, cracking susceptibility, pericarp wall thickness, and dry weight. Total marketable pepper yield ranged from 7.3 to 20.4 tons per acre with increasing nitrogen. It was determined that in a completely nitrogen depleted soil approximately 225-250 lbs N/A is needed to produce maximum yields with sufficient large size fruit in a 16-week crop grown under California's Central Valley conditions. Postharvest evaluations of mature green and red marketable fruit were inconsistent and indicated that nitrogen content was not necessarily a driving factor. Mature green fruit were firmer, had a thinner pericarp, and weighed less than red fruit. Red fruit dry weight increased with increasing nitrogen, but green fruit dry weight did not. Low nitrogen fruit color were less green and less red but no real separation of means by N treatment. Firmness, bruising, and cracking did not follow consistent trends in relation to N.

This page intentionally left blank



**California Chapter – American Society of Agronomy
2013 Plant and Soil Conference Evaluation**

Chapter web site: <http://calasa.ucdavis.edu>.

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 the next 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: _____
