American Society of Agronomy
California Chapter

Co-Sponsored by the California Plant Health Association

2018 Conference Proceedings

California Plant and Soil Conference

Intersection of Water and Nutrient Management

February 6 & 7, 2018

DoubleTree Hotel & Fresno Convention Center
2233 Ventura Street
Fresno, CA 93721

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2018 California Plant and Soil Conference

February 6-7, 2018

DoubleTree Hotel & Fresno Convention Center, 2233 Ventura Street, Fresno, CA 93721
Tel: 559-268-1000. http://calasa.ucdavis.edu

DAY 1 (Tuesday, Feb. 6th)

9:15 a.m **General Session Introduction:** Chapter President, Dr. Sharon Benes, California State University, Fresno

9:30 – 10:30 **Keynote Speaker- CA Secretary of Agriculture, Karen Ross (Salon B)**
How California will move forward in the next decade considering our droughts, environmental restrictions and increased reporting/certification and compliance activities.

MAIN SESSION: 10:35 a.m. – 12:10 p.m. (Salon B)

Main Session – Intersection of Water and Nutrient Management Chairs: Karen Lowell, Dan Munk & Michelle Leinfelder-Miles	
10:35	Introductory remarks
10:40	**Patrick Brown**, UC Davis, Dept. of Plant Sciences. *"Barriers to the Adoption of Recommended Nutrient & Water Management practices….."*
11:10	**Sarah Beganskas**, UC Santa Cruz, Dept. of Earth & Planetary Sciences. *"Case Study: Addressing Groundwater Recharge with an Eye to Water Quality"*
11:40	**Tim Hartz**, UC Davis, Dept. of Plant Science (emeritus) *"Irrigation Effects on Nitrogen Efficiency"*
12:10- 12:15	**Q&A/ Discussion (all speakers)**

LUNCH- DAY 1 12:15 – 1:25 p.m. (Salon C)

CONCURRENT SESSIONS: 1:30 – 3:00 p.m.

Session 1 – Nutrient Management Chair: Daniel Geisseler ***Salon A***		**Session 2 – Emerging Technologies for Improved Crop Management** Chairs: Mark Lundy & Andre Biscaro ***Salon B***	
1:30	Introductory remarks	1:30	Introductory remarks
1:35	**Randy Southard,** Dept. of Land, Air & Water Resources, UC Davis *"Potassium Fixation in California Soils"*	1:35	**Brian Speicher,** Applied Innovation Center, DRI *"Connecting High-quality Weather Forecasts with Pest Management Software"*
2:00	**Dan Putnam,** Dept. of Plant Sciences, UC Davis *"Phosphorus and Potassium Fertilization in Alfalfa"*	2:00	**Forrest Melton,** NASA Ames Research Center *"TOPS: Integrating Satellite and Weather Data for Irrigation Management"*
2:25	**Gene Miyao,** UCCE Yolo, Sacramento, Solano Co. *"Potassium Management in Processing Tomatoes"*	2:25	**Yufang Jin,** Dept. Land, Air & Water Resources, UC Davis *"Improving Irrigation Management with Remotely Sensed Images from Satellite and Drones"*
2:50-3:00	**Q&A/ Discussion (all speakers)**	2:50-3:00	**Q&A/ Discussion (all speakers)**

2018 California Plant and Soil Conference, February 6-7, 2018

DAY 1 (Tues. Feb. 6th) CONCURRENT SESSIONS: 3:25 – 5:00 p.m.

Session 3 – Pest Management Chairs: Rachel Naegele and Margaret Ellis *Salon A*		**Session 4 – Site-Specific Management** Chairs: Andre Biscaro & Mark Lundy *Salon B*	
3:25	Introductory remarks	3:25	Introductory remarks
3:30	**Tunyalee Martin,** Assoc. Director for Communications, UC-IPM *"UC IPM updates"*	3:30	**Steve Phillips,** North America Program, International Plant Nutrition Institute *"A Global View of Precision Agriculture: Opportunities for California"*
3:55	**Florent Trouillas,** Assistant Cooperative Extension Specialist Department of Plant Pathology, UC Davis, KARE *"Pathogens of fruit and nut crops"*	4:05	**Isaya Kisekka**, Dept. Land, Air & Water Resources, UC Davis, *"Introducing iCrop a Web-based Decision Support Tool for Optimizing Water and Nitrogen Management"*
4:20	**Jacob Wenger,** Fresno State, Dept. of Plant Science. *"Diagnostic test for the differentiation of different Lepidoptera species that impact almond and pistachio"*	4:30	**Curran Hughes**, Manager of Strategy, The Wonderful Company. **"***Mapping Soil Variability to Inform Gypsum Application in a Commercial Tree Nut Setting – Challenges and Opportunities"*
4:45-5:00	**Q.A./ Discussion (all speakers)**	4:55-5:00	**Q.A./ Discussion (all speakers)**

EVENING SOCIAL (Tues. Feb. 6th) – POSTER SESSION, WINE & CHEESE RECEPTION (5:00 pm, Salon D)

DAY 2 (Wed. Feb. 7th) CONCURRENT SESSIONS: 8:30 – 10:00 a.m.

Session 5 –Soil Biology & Soil Health Chairs: Karen Lowell, Daniel Geisseler, Eric Ellison *Salon A*		**Session 6 – Sustainable Use of Water** Chairs: Sharon Benes & Dan Munk *Salon B*	
8:30	Introductory remarks	8:30	Introductory remarks
8:35	**Will Horwath,** Dept. of Land, Air & Water Resources, UC Davis. *"How much can soil organic matter realistically be increased with cropping management in California?"*	8:35	**Representative,** Central Valley Regional Water Board and **Dane Mathis**, CA Dept. Water Resources. *Brief Overview: Salt and Nutrient Management Plans (SNMPs) and SGMA Implementation.*
9:00	**Jennifer Kucera,** Western Regional Soil Health Team Leader, USDA Natural Resources Conserv. Service, Portland OR *"Methods to track changes in soil biological properties under different management practices"*	9:00	**Panel Discussion (Growers)** • Mark McKean, President King's River Watershed Coalition Authority & diversified farmer. • Don Cameron, Terranova Farms, Helm • Phil Shepard, E.W. Merritt Farms, Porterville
9:25	**Gerald Davis**, Agronomist and PCA, Grimmway Farms, Bakersfield, CA *"Practical Considerations Toward Improving Soil Health and Functionality: Observations from One Organic Farm after 25 Years"*		**Moderator: Sarge Green,** **CA Water Institute, Fresno State**
9:50-10:00	**Q.A./ Discussion (all speakers)**	9:50-10:00	**Q.A./ Discussion (all speakers)**

2018 California Plant and Soil Conference, February 6-7, 2018

DAY 2 (Wed. Feb. 7th) CONCURRENT SESSIONS: 10:25 – 12:00 p.m.

Session 7 – Applied Crop Management Chairs: Stan Grant & Michelle Leinfelder Miles *Salon B*			**Session 8 – Managing Farm Energy** Chair: Dan Munk *Salon A*	
10:25	Introductory remarks		10:25	Introductory remarks
10:30	**Dirk Holstege,** Director, UC Davis Analytical Lab *"Understanding and Interpreting Soil and Plant Tissue Lab Reports"*		10:30	**John Weddington,** Center for Irrigation Technology, Fresno State *"Minimizing Energy Loss in Irrigation System Design and Maintenance"*
10:55	**Wes Asai,** Pomologist, Pomology Consulting *"Applied Advancements For Improving Yield and Quality of Treefruit and Nut Crops"*		10:55	**Bill Green**, Center for Irrigation Technology, Fresno State, *"Understanding Basic Pump Efficiency Calculations"* and **Greg Allen,** VP and Partner, Red Trac LLC "*Continuous Pump Efficiency Reporting*"
11:20	**Michelle Leinfelder-Miles,** Farm Advisor, UC Cooperative Extension, San Joaquin Co. *"Salinity Management – Soil and Cropping Systems Strategies"*		11:20	**Marshall English and Arian Aghajanzadeh,** Oregon State University and Lawrence Berkeley Lab. "*The Confluence of Irrigation Management and the Energy Grid– Reducing the energy footprint of water"*
11:45-12:00	**Q.A./ Discussion (all speakers)**		11:45-12:00	**Q.A./ Discussion (all speakers)**

BUSINESS MEETING & LUNCH 12:05 – 1:45 p.m. Salon

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GRADUATE STUDENT POSTERS—Ph.D. candidates

PROFESSIONAL (NON-STUDENT) POSTERS

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California Chapter of the American Society of Agronomy (ASA)
Board Meeting Agenda
February 1, 2017
Doubletree Hotel and Conference Center, Fresno, CA 12:05 – 2:00 p.m.

1. **Call to Order: Bob Hutmacher, President**, California Chapter ASA.

   a. President Hutmacher thanked everyone for attending the conference which by his estimate, would be the 46th annual conference and business meeting of the Society. The governing board offering the conference is a volunteer run organization, and the chapter's annual meeting has been running since 1972; one of the longest running conferences in California and one of the few that still prints Conference Proceedings.

   b. Reminder that attendees receive a paper copy of the proceedings, but this year's Proceedings, and all those dating back to 1972, are available online (calasa.ucdavis.edu). The on-line version of this year's proceedings will also include a couple of papers that were received, but are missing from the printed version).

   c. Conference evaluation forms are available on the tables and are also found in the proceedings (last two pages). Please fill them out with your comments or suggestions. The evaluations are read by the governing board and they provide valuable feedback on ALL ASPECTS OF THE CONFERENCE (location & venue, arrangements, speaker/ topic suggestions and suggestions for future Board members and Chapter Honorees)

   d. THANK YOU's:

      i. SPEAKERS: First, we would like to acknowledge the great contributions of our speakers, including our keynote speaker to this conference, Dr. Ken Cassman. A great amount of thought goes into the development of sessions that will be of interest, and we appreciate the efforts made by our speakers to have engaging talks that encourage questions and participation.

ii. STUDENT HELPERS: (1) Student participants in the SCHOLARSHIP and POSTER contest, and (2) Student Helpers who set up the poster boards, helped with signs, helped with registration and overall set-up. Students present at the lunch were asked to stand (for applause) and to be acknowledged — although many had to head back to the university and other duties.

iii. Kay Hutmacher (for once again providing the poster printing and the signs for the Conference)– her fifth year of doing this. There may be other spouses of board members who ended up doing things to help with the conference, so we thank them, too.

iv. SPONSORS: the board wants to acknowledge once again the many sponsors listed in the Proceedings and on the SPONSOR POSTERS for providing funds for student awards, travel support for some of our speakers and honorees, and for session breaks and the evening wine and cheese social during the poster session. Those sponsors included:

l. Western Plant Health Association
2. Dellavalle Labs,
3. Denele Analytical Inc,
4. Mid Valley Agricultural Services
5. Innovative Ag Services, LLC
6. Prime Dirt
7. Valley Tech Analytical Laboratory Services 8. FGL Analytical Chemists (Fruit Growers Labs)
9, Vanguard AG
10. TAP
11. Irrigation Matters
12. IAP Integrated Agricultural Professionals
13. Cal GAP

v. In particular, we acknowledge the long-term support, given again this year by Renee Pinel and the Western Plant Health Association who sponsored the entire student scholarship ($1500).

vi. We would also like to acknowledge the support from our paying attendees - <u>CA ASA is non-profit chapter of ASA and the meeting registration fees help to pay for conference costs…..so you all are sponsors, too. We THANK YOU.</u>

e. INTRODUCE the Governing Board and Executive Committee of the CA Chapter of the ASA (board members stood as their names were called and their hard work in planning the sessions and for some, serving on the scholarship and poster committees, was acknowledged. The Executive Board was then announced, asked to stand and their efforts at leading the board and overseeing the conference were also acknowledged.

Executive Board

i. Richard Smith: Past President
ii. Bob Hutmacher: President
iii. Sharon Benes: 1st VP
iv. Dan Munk: 2nd VP
v. Karen Lowell: Secretary/Treasurer

Serving again for 2017-2018 (one more year) on the Governing Board:

1. Andre Biscaro
2. Margaret Ellis
3. Dave Holden

Completing their first year on the board, with two more to come:

l. Rachel Naegele
2. Stan Grant
3. Mark Lundy

Completing their 3-year term on the Governing Board at this meeting

l. Eric Ellison
2. Anne Collins Burkholder
3. Hossein Zakeri

WE ESPECIALLY WANT TO THANK ERIC, ANNE and HOSSEIN for their service on the Board, and appreciate all of their service the past three years

We rely fully on this Governing Board for all aspects of setting up and running the meeting; in particular coming up with ideas for the sessions and identifying speakers. We therefore thank all of the board members for their hard work in preparing this year's CA Plant and Soil Conference. Board member positions are all volunteers, and we appreciate very much the time the time that they dedicate.

f. PAST PRESIDENTS of the Chapter who were in attendance at the meeting were also asked to stand and were acknowledged for their service in the past.

2. Business meeting minutes from the 2016 ASA Plant and Soil Conference were read (Bob)

a. Minutes of the Feb. 2, 2016 conference (starting on page 2 of the proceedings) were summarized. Call was made for questions and a motion was requested to approve the minutes.
   i. Motion made by Sharon Benes
   ii. Seconded by Stan Grant
   iii. Minutes for the 2016 business meeting were approved as presented

3. Treasurer's Report (Karen Lowell)
   a. Karen Lowell presented the current Treasurer's report that wraps up once 2016 conference expenses are in.
   b. A motion was requested to approve the Treasure report
      i, Motion made (Nat Dellavalle) and seconded (Sharon Benes)
      ii. Treasurer's report was approved.
   c. Karen extended her thanks, in particular, to Penny Cromwell for her assistance with all aspects of registration and many other miscellaneous tasks.

4. Nomination and Election of new individuals to serve on the Governing Board (Bob Hutmacher)
   a. Brief overview of the Governing Board structure was given:

      i. 9 regular Board members serving 3-year terms plus a 5 member Executive Board . According to the by-laws, members on the Board represent diverse disciplines with the goal being to represent academia, government agencies and industry.
      ii Executive Board members serve a five-year sequence, serving as Secretary Treasurer, then Second VP, First VP, President and Past President.
      iii. Governing Board members serve three year terms, with three members cycling off and three new members joining the ranks each year
      iv. Before nominations were received, the Past President, Richard Smith and the Board Members completing their term of service: Eric Ellison, Annc Collins Burkholder, Hossein Zakeri were acknowledged and thanked for their dedication and hard work.

Moved on to CA-ASA Board nominations:

EXECUTIVE COMMITTEE:

v. <u>Nomination received for Eric Ellison to join the Executive Board</u>
   A motion was entertained to accept the nomination of Eric Ellison.
   1. Motion made (Stan Grant) and then seconded.
   2. Motion passed.

vi. <u>Nominations for 3-year terms for the Governing Board:</u>
   Nominations received for:

1. Michelle Lienfelder Miles
2. Daniel Geisseler
3. Tom Gerecke

A motion came forward (Stan Grant), was seconded and passed to accept all three nominations to the Governing Board

5. Presentation of awards to 2017 honorccs (Richard Smith)
   a. Presentation of Honorees:
      i. Ron Brase (by Brooke Gale)
      ii. Ken Cassman (by Richard Smith, written by Bruce Roberts)
      iii. Bill Peacock (by Mary Bianchi)
      iv. Oliberio Cantu (by George Fohner)

6. Student Scholarship Award (WPHA) — (Karen Lowell)
   a. Karen Lowell (Chair of student scholarship committee).
      i. Karen acknowledged the other committee members (Hossein Zakeri, Eric Ellison) as well the support from sponsors (Western Plant Health Association and others).
      ii. Discussed the criteria used to judge the students; in addition to their essay, applicants were asked to provide two letters of recommendation and a description of their work aspirations.
      iii. Introduced representatives from the Western Plant Health Association (if present)

   b. Scholarship winners were announced and it was pointed out that their essays could be found in the Proceedings (beginning on page 15). The students could not be present due to the need to travel back for classes, but their accomplishments were acknowledged. First and second prize were awarded, respectively, to:

      i. Suzette Nicole Tumer, California State University Chico
      ii. Samuel Koehler, University of California, Davis

7. Student Poster Awards were presented by Anne Collins Burkholder (Poster Committee Member)
   a. Poster committee (Andre Biscaro- Chair, Anne Collins Burkholder and Rachel Naegele) were introduced and their efforts were acknowledged, along with multiple assistants who reviewed during the poster session.
   b. Thanks were given to the student volunteers from Fresno State for mounting the poster boards.
   c. Awards were made to graduate and undergraduate students.
   d. Undergraduate poster winners included:
      - Alexis Jackson (CSU Fresno): 1st place

- Jessie Brazil (CSU Fresno): 2nd place
- Laura Boots (CSU Chico)

e. Graduate Students (M.S.) winners were:
   - Giuliano Galdi (CSU Fresno): 1st place
   - Touyee Thao (CSU Fresno): 2nd place
   - Amninder Singh (CSU Fresno): 3rd place

f. Graduate Students (Ph.D.) winners were:
   - Deirdre Griffin (UC Davis): 1st place

8. Old business and New business
   OLD BUSINESS? None

   NEW BUSINESS? None

9. SURVEY / CONFERENCE EVALUATION FORMS: reminder given to complete forms and submit at registration table or box passed around when meeting was adjourned.

10. Outgoing President Bob Hutmacher: *I have enjoyed serving on the Governing Board and the Executive Board, and I have the responsibility as the current CA ASA Chapter President to now pass the gavel (specially made for the ASA California Chapter in 1978 with unique woods, including one of historical significance) over to Sharon Benes, the new incoming President. I'll now turn over the program to Dr. Sharon Benes, the new chapter President of the CA ASA*.

11. Incoming President Sharon Benes: thanked the audience for their attendance and adjourned the business meeting at 2 PM.

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	2013	Dave Goorahoo
1975	Oscar E. Lorenz	2014	Steve Grattan
1976	Donald L. Smith	2015	Richard 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	VashekCervinka	2014	Gene Aksland
1990	Parker F. Pratt		Richard Rominger		Kerry Arroues
1991	Francis E. Broadbent		W.A. Williams		Stuart Pettygrove
	Robert D. Whiting	2004	Harry Agamalian	2015	Bob Beede
	Eduardo Apodaca		Jim Brownell		Carol Frate
1992	Robert S. Ayers		Fred Starrh		Allan Romander
	Richard M. Thorup	2005	Wayne Biehler	2016	Larry Schwankl
1993	Howard L. Carnahan		Mike Reisenauer		Scott Johnson
	Tom W. Embelton		Charles Schaller		Joe Fabry
	John Merriam	2006	John Letey, Jr.	2017	Ronald J. Brase
1994	George V. Ferry		Joseph B. Summers		Kenneth G.Cassman
	John H. Turner				William L. Peacock
	James T. Thorup				Oliberio Cantu

American Society of Agronomy

California Chapter

2018

Honorees

Tim Hartz
Peter B. Goodell
Jose I. Faria

Tim Hartz

University of California, Davis. Cooperative Extension Vegetable Specialist

Tim Hartz was raised in Dayton, Ohio, and earned a degree in biology from nearby Bowling Green University. His career in agriculture began with a master's degree in horticulture from Colorado State University, followed by a Ph.D. from Virginia Tech. Tim joined the faculty of Texas A&M in 1981 as an Extension Horticulture Specialist, working with the vegetable industry in the Rio Grande Valley. Six years later he became the production manager for the division of Chiquita Brands that sourced melons and citrus from Texas, Mexico and various locations throughout Central America.

Tim joined the University of California in 1989 as an Extension Vegetable Specialist, briefly at UC Riverside before transferring to UC Davis. Dr. Hartz remained in that position until his retirement in 2017. In his 28 years as an Extension Specialist, Tim collaborated and supported UC farm advisors in all vegetable growing regions of the state. Tim's work on a wide range of crops and issues was a classic example of the right person at the right time. His research program and close working relationships with farm advisors, crop advisers and growers facilitated the movement of the vegetable industry to an elevated level of understanding of nutrient and irrigation management.

Tim introduced the soil nitrate quick test to the state in the early 1990's and developed this technique for both cool and warm season vegetable production systems. It facilitated an understanding of the value of residual soil nitrate and its importance to crop growth and yield. This concept now stands as a key practice used by the vegetable industry to improve nitrogen use efficiency. Initially many growers rejected this technique, but Tim knew that change was coming to the vegetable industry. He took short sabbaticals to Oregon in 2001 and to Florida in 2005 to study newly enacted water quality regulations and how they affected growers. He rightfully understood that California would follow suit. As a result, when the regional water quality control boards began enforcing the agricultural discharge waiver under the Porter-Cologne Act, Tim was able to help the California industry begin the long process of complying with the new sets of regulations impacting key vegetable production regions of the state, such as the Central Valley's Region 5 and the Central Coast's Region 3. Tim's focus was helping growers comply by improving nutrient management efficiency with practical solutions.

Although Tim is probably best known for the soil nitrate quick test, his research program greatly improved our understanding of crop nutrient requirements for commercial vegetable production. Examples include nitrate mineralization in California soils, crop residue mineralization, mitigation of nitrate in tile drain water, nitrogen, phosphorus, potassium and calcium nutrition of vegetables including for organic production, yellow-shoulder disorder of processing tomatoes and irrigation management of vegetables, especially helping processing tomato growers make the transition from furrow to drip irrigation while balancing yield with fruit quality. All of these research projects have Tim's distinctive fingerprint of keen insights leading to practical and economical solutions. Tim was patient with those who sought his counsel for their notion of management solutions to nutrient issues in California vegetables and always provided clear insight into the science and what was practical.

Tim was the mentor to a whole cohort of farm advisors, crop consultants, growers, and graduate students. He chaired the UC vegetable crops work group and was the UC liaison officer to the California Melon Research Board. He was a key contact to advise agency and regulatory staff on issues of nutrient management and compliance with the water quality regulations and his patient guidance and clear explanations were greatly valued. He served on the board of the California Certified Crop Advisor program, helped revise the CCA exam and developed the training program for the CCA N management certification. Tim was the key speaker on nutrient management at over 500 grower meetings, trainings and field days, as well as at statewide and scientific conferences. He wrote numerous publications on nutrient and irrigation management that will serve as the basis of our understanding on these subjects for many years to come. We are fortunate that Tim summarized his substantial research in a forthcoming UCANR publication, "Efficient nutrient management in California Vegetable Production". Everyone interested in nutrient management should have a copy of this book, as it provides a clear summary of the insights Tim brought to the area of nutrient management over his career.

In retirement Tim is active consulting with the South San Joaquin Valley Water Quality Coalition on their response to water quality regulatory challenges. He enjoys biking adventures with his wife, Marcia, and trying to remember how to play golf.

Peter B. Goodell

University of California, Cooperative Extension IPM Advisor

Pete Goodell was raised in a big family here in California, where he early on developed an interest in field ecology and biology. His long-term efforts in cultivating field research skills in biology, nematology and entomology have served him well over the years, and have helped him and cooperators develop options and workable solutions for a wide range of new, developing and ongoing pest management problems. After completing a Bachelor's degree in Ecology/ Field Biology at San Francisco State University, he jumped into agricultural research by signing on to collect insect samples in Los Banos area cotton fields early in his career. Pete described it as a job that "got me outdoors and was very satisfying" and one where "I was able to use a lot of what I learned in field biology at San Francisco State". That job helped expand his interest in agricultural entomology, and he continued his education at University of CA, Riverside, obtaining an M.S. degree (1979) and Ph.D. degree (1986) in Nematology and Entomology.

Close to the time that Pete finished his formal education at the University of California, the state of California started to implement new regulations aimed at reducing pesticide use, and state funding helped the University of California to create the UC Statewide Integrated Pest Management Project (UC-IPM). Goodell was described by Frank Zalom, former UC-IPM Director as "a key player in getting UC-IPM off and running, being a member of the first team of academics hired to conduct research and extension education to address some of these mandates of the state of California while keeping a focus on what might actually work for agricultural producers". UC-IPM was developed as an interdisciplinary program and for multiple crops, Pete both led and served as part of a team of researchers and educators who conducted research, came up with best management practices and summarized recommendations that took the form of IPM manuals, books, leaflets, training resources of all kinds, and more recently, website posts and blogs.

His research and education efforts have been diverse and demonstrate a wide range of capabilities and interests, including the development of management tools for lygus and root knot nematode, analyses of landscape ecology and cropping systems changes that impact the approach to consider (what works and what might not) in regional IPM strategies covering areas much larger than individual farms, developing strategies for aphid and whitefly control for sticky cotton prevention, GIS technology and mapping as part of analysis for regional pest management, and the development and use of computer programs for crop and insect management. In his career, Pete has repeatedly been called upon to help develop strategies for management of new or expanding pest problems in multiple crops, including pest identification, assessments of economic impacts, and dealing with requests for assistance in pesticide registrations. Field research of his own and in cooperation with others has provided a diversity of pest control options in multiple crops, but in addition, Pete has demonstrated over the years a true appreciation of the knowledge of PCA's and other industry professionals and the value in listening to and working with them to better understand the realities of field situations and considerations if you want to implement useable management strategies.

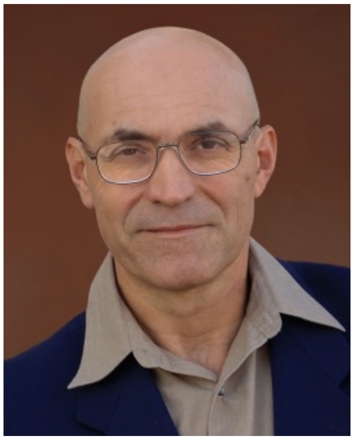
Within the IPM program he has served multiple roles in addition to Area IPM Advisor, including IPM Extension Coordinator, Associate Director of IPM at Kearney Ag Center, and multi-year roles as Interim Director and Co-Associate Director of the UC Statewide IPM Program. Many innovative ideas came out of a wide range of UC-IPM efforts, and multiple colleagues expressed their appreciation for Pete's numerous efforts to try new approaches in extension education, implementing the social sciences and alternative information delivery approaches to see how people might best learn about and adopt pest management strategies.

Dr. Goodell has received multiple other awards in addition to being made an honoree of the CA Chapter of the American Society of Agronomy, including two Distinguished Service Awards from UC Agriculture and Natural Resources, CDPR IPM Innovators Award, Entomological Society of America Pacific Branch Award for excellence in IPM, and Lifetime Achievement awards from the Association of Applied IPM Ecologists and from California Cotton Growers and Ginners Association.

Pete will likely be a very active retiree, with many interests related to his more time to spend with his family, his passion for more exploration of the Sierras and the great outdoors; as well as the fact that he applied for emeritus status with the University so that he could continue work on key projects that interest him. As most of us have experienced, Pete often concluded his presentations with beautiful photos from some of his hiking and backpacking adventures, so get out there and you will probably cross paths in the future.

José I. Faria

Chief, Special Investigations Branch and Leader, Agricultural Drainage Program, California Department of Water Resources



Born on the Portuguese island of Madeira, José was the son of a seamstress and a farmer. In 1958, his father grew tired of farming and immigrated to Caracas, Venezuela, where he opened a business, and two years later the rest of the family followed. José worked in his father's business in the morning and attended high school in the afternoon and evening. After graduating from high school, he became a Venezuelan citizen and attended Avila University to study Chemical Engineering for two years. When the private university had financial problems and closed, he traveled through the countryside of Venezuela and Colombia for a year. He then applied to a Venezuelan government program offering educational scholarships overseas and was selected to study Civil Engineering in the U.S. He attended California State University, Fresno, met his wife, and graduated in 1983. They returned to Venezuela to fulfill his contract, but the Venezuelan government did not have a job for him, so he came back to the U.S. and obtained a job with a small engineering firm working under a contract with the City of Dinuba.

Later José applied for Civil Engineering jobs at State agencies, and started in May 1985, as a Junior Civil Engineer in Water Resources at the Department of Water Resources (DWR), San Joaquin District office in Fresno, eventually working himself up to the position of Chief of Special Investigations. At one time, José had responsibility for six sections including Aqueduct Protection and Flood Management, Groundwater and Regional Planning, Surface and Groundwater Data, Drainage Management, River Restoration and the Environmental Services Section, and he was also a Watershed Coordinator. The San Joaquin District was reorganized several times, eventually becoming the South Central Region Office. Sections were added and removed, but a constant was the Agricultural Drainage Program. In February, 2017, José Faria retired after 32 years of service.

Managing the Agricultural Drainage Program lead to the development of an innovative method for farmers to manage agricultural drainage water: Integrated on Farm Drainage Management (IFDM) which involved the reuse of the saline drainage water on increasingly salt tolerant crops, including forages and halophytes, with final evaporation to dryness in a solar evaporator. The method was accepted by the State Water Board and key environmental organizations, but discharge into a solar evaporator required a special waiver to the Ag Discharge requirements which was achieved through State Senate Bill 1347. IFDM was successfully implemented on two commercial farms (Red Rock Ranch in Five Points and Andrew's Ag in Kern County) and on a regional scale, in the now 6,000 acre SJRIP (San Joaquin River Improvement Project) operated by Panoche Drainage District. The SJRIP manages saline drainage water for 98,000 acres of productive farmland in the Grasslands Area and through reuse on salt tolerant forages, it has reduced drainage discharge and salt, boron and selenium loading into the San Joaquin River by 84%, 72% and 94%, respectively, since its inception in 1998. IFDM developed a number of salt tolerant crops that have been successful at a commercial level and it lead to the planting of thousands of trees to evaporate drainage water and lower perched water tables.

As leader of the Ag Drainage Program, José represented DWR in public policy meetings related to salinity issues in the Delta, the San Joaquin River, and the San Joaquin Valley; as well as in drainage solution settlement negotiations, public hearings related to permits and conditions, implementation of the Southern Delta Salinity Objectives, and board planning for long-term management of salinity in the Central Valley. In March of 2009, José was interviewed by a National Geographic writer on technologies for salinity management. Today, solar evaporators have replaced two evaporation ponds in the valley and Westlands Water District has considered using them for part of an eventual drainage service solution. José still receives inquiries from around the world about solar evaporators and how to manage them.

José also managed DWR's grants programs including Proposition 204 (drainage reuse), and Proposition 84 (Delta Water Quality San Joaquin River), and the Agricultural Drainage Management Program which has funded over $50 million in research projects involving reuse and desalination of agricultural subsurface drainage water and brackish groundwater. With DWR staff, UC, USDA and Fresno State researchers, he initiated the testing of numerous new technologies for salt harvesting and purification, reverse osmosis, identification and cultivation of salt tolerant forages and halophytes and even the introduction of Argentine clones of *Prosopis alba* (mesquite) for the production of high quality wood. Success is difficult in the face of salinity, but José never gave up in the face of adversity. What José's colleagues and friends will remember is the quiet and professional way in which he worked through complex and politically contentious salinity, drainage, and water quality issues that involved the agricultural community, environmentalists and water quality regulators with such skill, grace and optimism.

Looking back on his 32-year career with DWR, José feels privileged and thankful for having a great career with the agency, especially for managing the Agricultural Drainage Program that has left a legacy of accomplishments for Salinity Management in the Valley.

Now that José is retired, he looks forward to working on his farm, traveling and working on charity projects with the local Rotary Club and helping his son in his engineering consulting business. He will also continue with his wine-making. In 2015, his homemade red wine Touriga Red, won a Gold Medal in a national amateur wine competition from the American Wine Society. The vines came from cuttings of a unique, local mother-vine that his grandfather planted long ago on the island of Madeira, Portugal.

American Society of Agronomy
California Chapter

2018 Scholarship Committee

Eric Ellison, Chair
Robert Hutmacher
Margaret Ellis

Recipients and Essays

Essay Question:

The McKinsey Global Institute recently described twelve disruptive technologies that will transform life, business, and the global economy. For more information, visit the website: https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/disruptivetechnologies.

Review the information provided by the McKinsey Global Institute and describe how an agricultural practice in use today in California will change due to one of the disruptive technologies. What will the new technology do? Why would California farmers want to use it? Discuss the potential positive and negative impacts of implementing the technology. Do not dwell on whether or when the technology will be implemented, or exactly how the technology will work.Instead, assume the technology will eventually be developed and implemented by farmers.

2018 Scholarship Winner

Shannon Mayhew, University of California - Davis

Next Generation Genomics

Agriculture is facing increasing demands in an era with many unresolved and complex issues. To overcome these problems farmers need to adapt their crops and agriculture practices to accommodate both consumer demands and the environmental challenges they face. In order to do this next generation genomics will alter the way that farmers look at crops. This innovation holds promise for greater understanding of how traits in crops are largely dictated by genes. Looking beyond the DNA, genomics is promising in that it can further integrate understandings of RNA, proteins, and the nature of repetitive DNA or transposons. This understanding has also proceeded with the advent of technology that has facilitated targeting of these areas, altering crops in advantageous ways. This technology may offer positive benefits for farmers, however, disadvantageous can also arise as a result of the drastic differences and novelty of the technology. In order to further understand the impacts for safe implementation of next generation genomics both sides of the issue must be considered.

Next generation genomics looks at nucleotide differences between organisms while also incorporating genomic information. Understanding the sequence of DNA has been the most popular innovation in the past and was used for marker assisted breeding to target traits of interests for agriculture. However, this area is expanding with knowledge of how epigenetic changes can also largely affect the phenotypic traits that are targets for farmers and consumer preferences. This requires integration of information from protemics, transcritomics, and related information of DNA sequences between interrelated crops. With understanding and unraveling of the DNA sequences, how alterations in targeted areas may then express a change in phenotype have advanced with the advent of new technology. One of these promising innovations is CRISPER-Cas9, which is of particular interest in that targeted sequences of the nucleotide can be altered by silencing the gene or by incorporating a novel gene into the sequence of organisms DNA.

This technological innovation and increased understanding of plants genomes will have direct impacts and implications for farmers. By targeting genes that can be used for increased yields farmers will have a greater economic advantage. This gives incentives to implement seeds from plants that were products of next generation genomics. Of more importance to farmers may be the resistance to pests that is facilitated by these technological innovations have. One of the largest impacts of pathogen resistance was been widely used in the papaya industry as protection against Papaya ring spot virus (PRSV). By understanding the sequence of the nucleic acid of this virus and then inserting this sequence into bacterial plasmids that express the coat protein Papaya trees have widely been protected from the virus when expressing the coat protein. This genomic advantage has been widely credited with “saving the Papaya industry in Hawaii” and similar methods have been employed in the case of squash and most recently plum. Farmer’s benefit from a transgenic approach in that without the coat proteins yields would be greatly reduced, this is due to the nature of viruses for which there are little alternatives for eradication. In these few cases it seems the public has accepted the use of transgenic technology. The reasoning for this acceptance varies due to a lack of alternatives or consumers are unaware.

Genomic innovations have also allowed for swifter breeding, meaning the seeds are available for farmers to grow and consumers to purchase with less time devoted to the introgression of the desired trait. This is due to the ability to target smaller sequences and to sequence plants at younger ages in order to determine if the desired gene has been inserted. Only after subsequent generations are the plants then taken to field trials saving time and money. This allows farmers to have the most advantageous plants, which can be certified to have the desired phenotypes since sequencing makes this information available.

CRISPER-Cas9 and most recently CRISPER-Cas13 have been touted as novel technological innovations in next generation genomics. CRISPER-Cas9 is promising for markets that do not have the approval of the public to genetically engineer plants. After edits are made using CRISPR-Cas9 plants in the ensuing generation can be selected for those without the T-plasmid, while still retaining the gene or edit. This benefits farmers in that unlike RNAi silencing they can market these crops with the desired traits that also have no foreign DNA. However, one issue that arises is that the DNA repair mechanism isn't controlled and so the level of silencing is not as extreme. However, greater precision in DNA cuts can be made with RNAi silencing. Other disadvantages that impede the development of such technology is when these plants are regenerated using callus or tissue culture. This form of regeneration of entire plants from totipotent cells can result in mutations to the gene of interest or unique chimeras. These hurdles have not hindered scientists from continuing to develop and refine CRISPER editing and they have recently developed CRISPER-Cas13, which is capable of editing RNA. In this way the genome is not altered, rather it is a form for transcriptome engineering. This will largely increase the amount novel alterations and improvements that can be developed for farmers and consumers.

Despite the many advantages that farmers gain from next generation genomics there are many questions and concerns that have been raised. One alarming issue that has ensued from unraveling the gene sequences of plants and organisms is the propriety nature of the information. Questions have arisen of whether large seed companies should have the ability to withhold the sequences of plants, and if this stifles scientific advancement. Another concern is the cost of such technology, and how this will influence the cost of seeds for farmers, and thus the cost of food for consumers. Hopefully such issues may be resolved since the cost of sequencing continues to drop each year. In the case of genetically engineered crops how the public reacts has largely turned farmers away from this technology. This lack of public support coupled with regulatory hurdles and the fact that there is potential for cross-pollination spreading the gene to neighboring non-genetically engineered crops has stifled the development of genomics technology. Issues arising from transgenic gene transfer by cross-pollination are of great concern since seed companies consider the gene propriety information that they own. When genes are found in neighboring fields that did not purchase the genetically engineered seed, the farmers are unable to harvest their crops. With further research of transgenic plants there is a greater need to incorporate a stably integrated gene that will not readily spread to the environment.

Further issues of transgenic breeding are positional affects, in which the foreign DNA can incorporate anywhere in the genome. The resulting novel trait in the genetically altered plant may therefore be to due to disruption of a gene rather than insertion of the desired trait. However, this issue may be resolved with the use of CRISPR-Cas9. If farmers are interested in utilizing innovations for understanding the sequences of their crops then these issues need to be resolved. Without the support of the market farmers will have no incentive to grow crops that have the disapproval of consumers. For centuries humans have altered the plants that they have depended on for life. Plants were domesticated into crops that largely diverged from their natural ancestors. Crops in themselves are a technological innovation that was achieved by man using simple breeding by selecting seeds from the most desirable crops. Farmers have acted on this tradition of crop improvement with next generation genomics, which continues this history of plant development. This newest stage in plant breeding is promising to farmers who will likely see desirable traits that may help in the increasing instability that we see farmlands having to contend with. However, the disadvantages to this newest development should not be hidden, only by overcoming the issues can we formulate a method that will widely implement next generation genomics. Next generation genomics has the ability to make the large-scale changes needed for our crops to resist increasing plant pathogens, soil salinity, high temperatures, soil erosion, and water instability. Change is needed now more than ever as our environment shifts in unprecedented ways with ensuing demands on agriculture development.

2018 Scholarship Winner

Jonathon Hubble, Fresno State University

The Internet of Things

It's not a secret that technology is becoming a larger part of our lives by the minute. It is transforming our lives and the industries in which we work and rely on for our sustenance. I don't believe this is truer in any industry more than it is in agriculture. The farmer of the 1950s would be unfamiliar with many practices and pieces of equipment that are commonplace on today's farms. I am a little embarrassed to admit that I was not familiar with the term 'internet of things' before reading the report put out by the McKinsey Global Institute. However, I have chosen to focus on how the internet of things will change the practice of irrigating and the components that go into making an irrigation schedule. I work for an agronomist and I am currently heavily involved in irrigation scheduling and to some extent, we are already seeing the internet of things play a role in changing how soil moisture is monitored and how irrigation decisions are made. I think we are just at the beginning of this shift and, due to this technology, I think scheduling an irrigation event will look very different 60 years from now.

According to the McKinsey report, the internet of things consists of embedding sensors and actuators in machines and other physical objects to bring them into the connected world. Applying this specifically to irrigation, this might consist of a series of soil moisture probes in a field that send data directly to a computer or smart phone through a wireless connection. The recipient would then be able to make the day to day or hour to hour decision to turn on a pump through that same computer or smart phone without having to physically go to the field. The application of this technology may also cut out the middle-man and allow the moisture sensors to send data directly to the pump itself. The pump would then be able to start itself once a pre-determined depletion level has been reached in the field. This technology would also be able to track and display flow rates, changes in pressure, and actual amounts of water applied and would be available whenever a manager or grower wants to view it. Look at the webpage of any large-scale irrigation systems company and you will find that most of them are starting to carry the sorts of technologies I have described. It is a far more efficient system than the one we have currently where technicians have to go into the field to start the pump and then manually open and close valves based on which part of the field they want to run. Depending how frequently the sets change, this could require having somebody on staff 24 hours a day to rotate irrigation sets. Having this system and data available to a grower would provide multiple benefits and would help to increase efficiencies while cutting costs.

The benefits of having sensors and actuators embedded in machines and then tied together through the internet are seemingly endless. Currently, most fields have some sort of sensor in them but the majority of them still have to be read by a technician on a regular basis, which can be expensive and require a lot of man-hours. Some fields, such as annual crop fields, may not have sensors in them and are instead hand probed on a regular basis to monitor moisture. This can be very subjective and you always run the risk of having a field skipped by a busy or distracted consultant. Having sensors that send remote data from every field would essentially eliminate human error and would reduce labor costs for everyone involved. Also, instead of getting weekly or semi-weekly moisture levels, that data would be available whenever a manager wants to get on the internet to check. In crops that are deficit irrigated, this could provide great benefits as a crop could easily go from properly stressed to overly stressed in a matter of days. With the implementation of SGMA on the horizon, I believe deficit irrigation will become more common so these technologies have the potential to be provide great benefits. From talking with growers, the cost and availability of labor is one of the biggest threats looming over agriculture's head. Being able to monitor moisture levels and execute an irrigation event without having someone physically in the field would save the grower money and allow them to stay in business. It seems entirely possible to have this sort of system tied to an on-farm weather station which would allow for more accurate ET data. This could potentially allow for the system to write its own ET schedules while accounting for on-farm rainfall totals. However, nothing is perfect or 100% efficient and this technology doesn't come without its negatives either.

Anytime a human is taken out of the decision-making process, you lose exactly what sets us apart: the ability to make complex decisions. In a system that operates remotely and autonomously, that system operates exactly as its programmed to and turns on exactly when it is supposed to. But irrigation scheduling is a complex process that requires many different pieces of information. The sensor in the field doesn't know things like the price and quality of the irrigation water or the weather forecast. It wouldn't be able to make decisions based on economic factors or work around things like spray cycles. It wouldn't be able to work with leaching fractions because it would be designed to turn the pump off at field capacity. I'm sure many of these issues could be addressed in the future but as it stands, I think there will always be a need for the human component in these decisions. This brings up the only other effect that could be seen as negative being that the job of an irrigation scheduler or manager could change due to this technology. The days of measuring moisture by feel could be coming to a close while the new manager or scheduler may spend more time looking at graphs and reports sent from the sensors. There will still be a need for an agronomist to understand plants, soils, water, and nutrients, but the day to day tasks may change with the full implementation of this technology. This technology may require that agronomists also have a thorough understanding of the new equipment and how to work with it to increase efficiencies.

Looking forward to the future, I believe the process of scheduling and conducting an irrigation event will change and is already changing due to the availability of the internet of things. The question that we should be looking at as agronomists and future agronomists is how we can work with this new technology to increase efficiencies while reducing costs, increasing yields, and avoiding environmental damage. The way of the future is going to be producing much more with much fewer resources, water being one of them. The applications of this technology are seemingly endless and the impact of using them seems that it will be overwhelmingly positive. I believe the internet of things is going to continue to revolutionize the way we conduct irrigation events and it is going to continue to help maximize efficiencies at all levels of the operation.

American Society of Agronomy
California Chapter

2018

Keynote Speaker

Karen Ross
CA Secretary of Agriculture

How California will move forward in the next decade considering our droughts, environmental restrictions and increased reporting/certification and compliance activities.

American Society of Agronomy

California Chapter

2018

Main Session

Intersection of Water and Nutrient Management

Session Chairs:

Karen Lowell, Dan Munk & Michelle Leinfelder-Miles

Irrigation Effects on Nitrogen Efficiency

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Keywords: A/R ratio, Distribution Uniformity (D.U.), ET_a,, nitrogen residence time

Introduction

Nitrate leaching from irrigated agriculture has been an environmental concern in California for decades. However, regulatory pressure on growers to limit nitrogen losses from their field operations has recently increased with the imposition of reporting requirements regarding on-farm nitrogen (N) balance. N balance compares the amount of N applied (all sources, including fertilizer, organic amendments and N in irrigation water) with N removed in harvested products. This 'A/R ratio' will be the main metric used by Regional Water Quality Control Boards to evaluate the N use efficiency of particular crops, and growers. While it is widely recognized that N efficiency is connected with irrigation management, many people underestimate just how integrally connected N management and irrigation management are. This paper discusses this link, and suggests ways to improve irrigation management to reduce N losses.

Linking irrigation management to N leaching loss

As an anion, nitrate (NO_3^-) moves freely with water through the soil; any water moving below the effective root zone will carry nitrate-nitrogen (NO_3-N) with it. Nitrate concentration in tile drainage provides an estimate of potential N leaching, since water reaching tile drains has moved below the crop rooting zone. Studies monitoring tile drain effluent in both the Central Valley (Letey et al., 1977) and coastal production areas (Hartz et al., 2017; Los Huertos et al., 2001) found NO_3-N concentrations > 30 PPM to be common, and much higher concentrations (> 100 PPPM) periodically occurring. That leachate NO_3-N concentrations are often in the range of 30-100 PPM is not surprising. Fertilized root zones often contain 5-30 PPM NO_3-N on a soil dry weight basis. However, all soil nitrate is in the soil solution, which in a mid-textured soil weighs only about 25% as much as the dry soil. This means that the NO_3-N concentration in the soil solution is about 4 times higher than if expressed on a dry soil basis. To put this NO_3-N loss potential in context, an acre-inch of leachate at 30 PPM NO_3-N carries approximately 7 lb N, or about 23 lb N if the concentration is 100 PPM NO_3-N. Clearly, leaching losses can add up to a substantial portion of an annual N balance unless irrigation is managed carefully.

The importance of nitrogen residence time

When N fertilizer is applied, the crop does not take it up all at once. Crops take up N to support new growth; the rate of that growth drives N uptake. Table 1 compares the rate of N uptake for important California crops. These rates apply to the period of the growing season when growth rates are at the maximum (after leaf-out until pre-harvest for perennial crops, post-establishment to preharvest for annuals). When typical sidedressing (50-100 lb N acre^{-1}) or fertigation (30-50 lb N acre^{-1}) occur, it will usually take many days for the crop to utilize the applied N. In the meantime, careful irrigation is required to minimize the movement of this N downward in the soil profile. Maximizing 'residence time' in the active root zone is critical to efficient N utilization.

Table 1. Typical rate of N uptake by selected crops during the rapid growth phase.

Daily N uptake (lb N $acre^{-1}$ day^{-1})		
< 3	3-5	> 5
almond	cotton	corn
citrus	lettuce	cole crops
grape	melon	high-density leafy greens (spinach, baby lettuce)
pistachio	tomato	
walnut		

There is limited margin for error, because the efficiency of N recovery drops quickly with soil depth. Fig. 1 shows the typical distribution of roots by soil depth for almond and broccoli. While both can develop roots below a depth of three feet, the vast majority of roots are contained in the top 2 feet. This pattern is characteristic of most crops - the top half of the root zone typically contains > 75% of total roots. The deeper NO_3^- moves in the soil, the less likely it will be taken up by the crop.

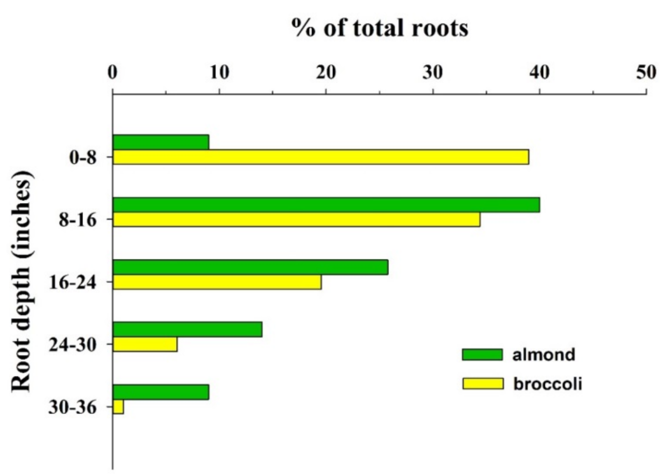


Fig. 1. Pattern of rooting in almond and broccoli; from Muhammad et al. (2016) and Smith et al. (2016).

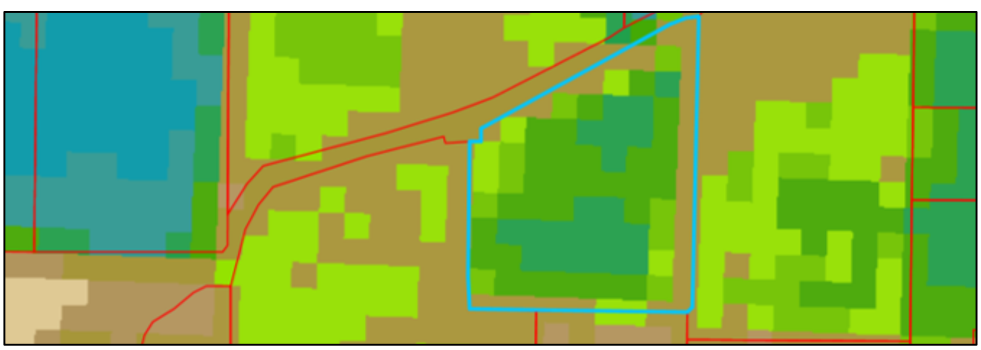
This obviously has implications for how fertigation is applied. Nitrogen in the form of NO_3^- or urea will move with the applied water; the earlier in the irrigation cycle fertigation is done, the deeper the nitrogen will go. As a general rule it is advisable to apply N later in the irrigation cycle, as long as irrigation continues for a period of time after fertigation is terminated sufficient to clear the N from the system before shut down. It is also important that the irrigations that follow sidedressing or fertigation not contain a substantial leaching fraction.

The importance of irrigation efficiency

Irrigation efficiency, the ratio of crop evapotranspiration to applied water, is controlled by two factors. The first is the distribution uniformity (DU) of the irrigation system. DU is calculated as the ratio of water applied to the driest quarter of a field compared to the overall field average. Surveys across the state have shown that DUs in commercial fields vary widely. The majority of low volume systems (drip or microsprinklers) run between 70-90%. For nitrogen efficiency the differences between a DU of 70% and 90% are profound. If an almond orchard has seasonal irrigation requirement of 40 inches, a microsprinkler system with a DU of 90% would require approximately 44 inches of irrigation to provide adequate moisture to all areas of the orchard. Conversely, if the DU was 70%, 57 inches of water would be needed to fully irrigate the orchard; in this situation there would be no way to avoid substantial N leaching loss.

The other factor controlling irrigation efficiency is the degree of retention of applied water in the active root zone. It is possible to uniformly distribute irrigation across a field and still have low irrigation efficiency; if the volume of water applied is too great to be held in the crop root zone, leaching loss is unavoidable. Irrigation frequency is the key. To determine the appropriate frequency one needs to know the available water holding capacity of the most limiting soil type in the field, the fraction of soil volume wetted by the irrigation system, and the degree of allowable water depletion appropriate to the crop. An on-line tool (https://casoilresource.lawr.ucdavis.edu/gmap/) allows the user to quickly determine the approximate soil water holding characteristics in a given field or orchard. Available water depletion for vegetable crops should be limited to not more than 20-30% in the active root zone; for permanent crops depletion of 50% is a reasonable target.

Another on-line tool (https://agmpep.com/variability/) provides an alternative way to evaluate irrigation efficiency. This tool utilizes satellite imagery to calculate seasonal actual ET (ET_a), and displays the pattern of ET_a across a field. Several important pieces of information can be gleaned from this tool. First, the average seasonal ET_a can be compared to the seasonal amount of irrigation applied to estimate overall irrigation efficiency. Second, it provides statistics on the distribution uniformity of ET_a within the field.



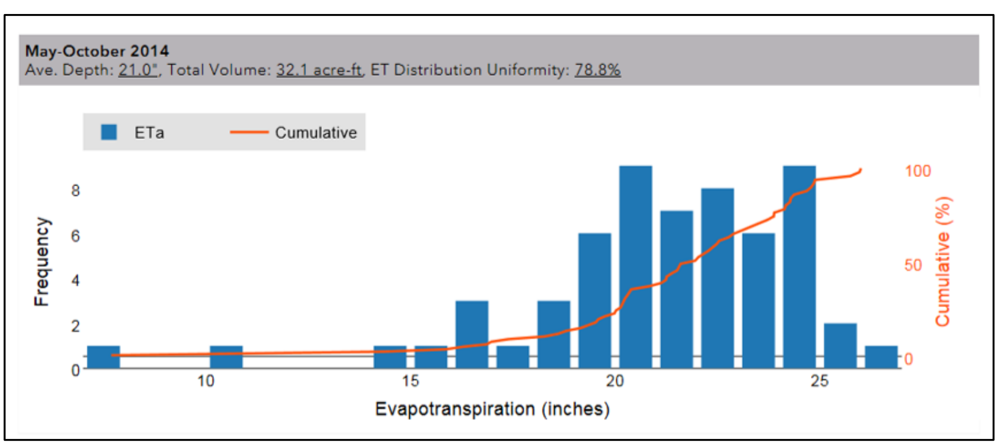


Fig. 2. Pattern of seasonal ET_a in an almond orchard (orchard highlighted in blue in the top image), and distribution uniformity of ET_a within that orchard (bottom image).

The imagery currently available in this tool is from the 2014 season, so it is most useful for mature permanent crops, for which seasonal patterns would be similar across years given consistent irrigation management. As is the case with irrigation DU, uniformity of ET_a varies widely from orchard to orchard, with a substantial percentage of orchards achieving an ET_a DU >85%, while many are <70%. Where an individual orchard shows high ET_a variability, or a mismatch between seasonal ET_a and seasonal irrigation volume, a grower should carefully evaluate current irrigation management practices.

Crediting N contained in irrigation water

The requirement to report the amount of N contained in applied irrigation water has focused attention on how one can safely adjust N fertilizer rates to account for the contribution of irrigation water NO_3-N. Unfortunately, there is no simple answer to this question, as the relative 'fertilizer credit' for irrigation water NO_3-N is situational. In a series of experiments with lettuce and broccoli, Cahn et al. (2017) showed that irrigation water NO_3-N was at least as efficiently taken up by crops as fertilizer N. However, in these trials drip irrigation was used, and only water applied after crop establishment was tracked. In these circumstances crediting 100% of irrigation water N against the N fertilizer rate may be appropriate; while some fraction of applied water may leach, the NO_3-N in that water, and fertilizer N in the soil, would be at an equal risk of leaching.

There are also situations in which the crop recovery of irrigation water N may be very poor. Pre-irrigation to fill the soil profile before planting an annual crop may place a substantial portion of the water NO_3-N deep enough to limit crop recovery; in this circumstance the most appropriate way to estimate the agronomic contribution of irrigation water N would be to conduct a post-establishment residual soil NO_3-N test. Where basin or furrow irrigation is used the practical limitations on irrigation efficiency mean that a substantial fraction of the N in the water immediately leaches beyond crop recovery. A grower should carefully consider the circumstances of individual field situations when estimating the fertilizer credit for irrigation water NO_3-N. This on-line tool (https://agmpep.com/calc-irrn/) calculates the effective N contribution in irrigation water, based on the grower-specified level of efficiency.

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American Society of Agronomy

California Chapter

2018

Session #1

Nutrient Management

Session Chair:

Daniel Geisseler

Management of Phosphorus and Potassium Fertilization in Alfalfa[1]

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INTRODUCTION

Alfalfa (*Medicago sativa* L.) represents a significant component of California's fertilizer footprint, especially for potassium and phosphorus due to its acreage and uptake levels. Greater than 800,000 acres of alfalfa were grown in California in 2017, producing 5.35 million tons of hay and haylage, largest of any state in the US. It is the most critical feed for the state's #1 agricultural enterprise, dairy. Yields in California are among the highest in the US – mostly averaging 6 to 9 tons/acre, but ranging from 4 to 15 tons/acre depending upon location (statewide average is 6.7 t/a = 15 MT/ha, USDA-NASS, 2017).

Phosphorus (P) is typically the most limiting fertility factor for alfalfa in California (Figure 1), followed by potassium (K). The high yields of alfalfa have important implications for nutrient management (Table 1). Since the entire above-ground crop is harvested, soils may become deficient after several years of production, unlike grains or fruits when only a portion of the crop is removed.

Figure 1. Strip without fertilizer indicates yield response to P. It's always useful to include non-fertilized controls to determine whether a fertilizer application is effective. Photo: Intermountain region.

[1] Putnam, D.H., N. Clark, and D. Geisseler. 2017. Management of Phosphorus and Potassium in Alfalfa. IN Proceedings, 2017 California Plant and Soil Conference. 31 January – 1 February, 2017, Fresno CA. California Chapter American Society of Agronomy. See: http://calasa.ucdavis.edu/Conference_Proceedings/. We express deep thanks and acknowledgement to Steve Orloff, UCCE Farm Advisor, now deceased, for many years of collaborative work on this project. We express great sorrow at his untimely passing in 2017.

Nitrogen. While alfalfa also has very high levels of nitrogen uptake, it is also a vigorous N_2 fixer (biological), and so normally N is not considered a limiting nutrient for alfalfa production and N fertilizers are not generally recommended (Long and Putnam, 2013). However, alfalfa can contribute significant N to cropping systems in rotation and alfalfa can play a role mitigating excess N (See Putnam and Lin, 2015 for a more complete discussion of the role N in alfalfa cropping systems).

Table 1. P & K Nutrients removed in an alfalfa crop at various yield levels.

	Forage Yield Level					
	4 t/a	6 t/a	8 t/a	10 t/a	12 t/a	14 t/a
Nutrient	Nutrient Removal (lbs./acre)					
Phosphorus (P_2O_5)	21(47)	31 (71)	42(95)	52 (119)	62 (143)	72 (165)
Potassium (K_20)	160(192)	240(288)	320(384)	400(480)	480(576)	560(672)

Adapted from: Meyer et al., 2007.

PHOSPHORUS & POTASSIUM MANAGEMENT

In general an integrated approach which includes soil testing and plant sampling is recommended. The range on a specific soil will indicate whether P is likely to be an important limiting factor or not (Table 2). However, soil testing alone is likely not typically adequate, since this is a multi-year crop with high uptake levels, and a combination of soil and plant sampling is recommended. Deficient soils typically require long-term approaches to build up P supplies for alfalfa. Since P is generally not lost from most CA alfalfa fields by soil erosion in

Table 2. Interpretation of soil test results for alfalfa production. An economic yield response to fertilizer application is very likely for values below the deficient level, somewhat likely for values in the marginal range, and unlikely for values significantly over the adequate range.

		Soil Value (ppm)			
Nutrient	Extract	Deficient	Marginal	Adequate	High
Phosphorus	Bicarbonate (Olsen P)	<5	5-10	10-20	>20
Potassium	Ammonium acetate	<40	40-80	80-125	>125

Adapted from: Meyer et al., 2007.

alfalfa, growers can attempt to build P in anticipation of long-term productivity. Phosphorus is particularly challenging for organic producers, since inexpensive P organic fertilizers are not readily available. Manures are often excellent sources, but may require long-distance transport and/or high expenditures. Typically, inexpensive sources of P are recommended, and foliar applications are not generally very useful, due to their short-term impacts, costs, and the multiple harvests of this crop.

Yield Response to Phosphorus. On P-deficient soils, alfalfa responds readily to additions of P fertilizers (Figure 1 and 2). The most dramatic increases in yield due to fertilizers are seen in the first additions (e.g. the first 50-100 lbs. P_2O_5/acre) in many studies done over the years. As Figure 2 indicates, there was a significant gain of up to 1.5 t/a hay up with fertilizer applications up to 150 lbs. P_2O_5, but responses were modest after this point: only ½ ton (if at all) above that rate (depending upon the data point chosen-Figure 2). It's important to determine the economic worth of the crop in relationship to the cost of fertilizers. In addition, contributing P fertilizers to long-term build-up must be considered. If the economic value of the crop is low in a given year, applications can be perhaps moderated or postponed, but as we have reported elsewhere, scrimping on P fertilization does not make sense, especially the first increment of applications (Orloff & Putnam, 2016). The typical yield response to P on depleted soils of 50-100 lb. P_2O_5/acre of about 1 ton/acre is very likely to be cost effective even with low hay prices.

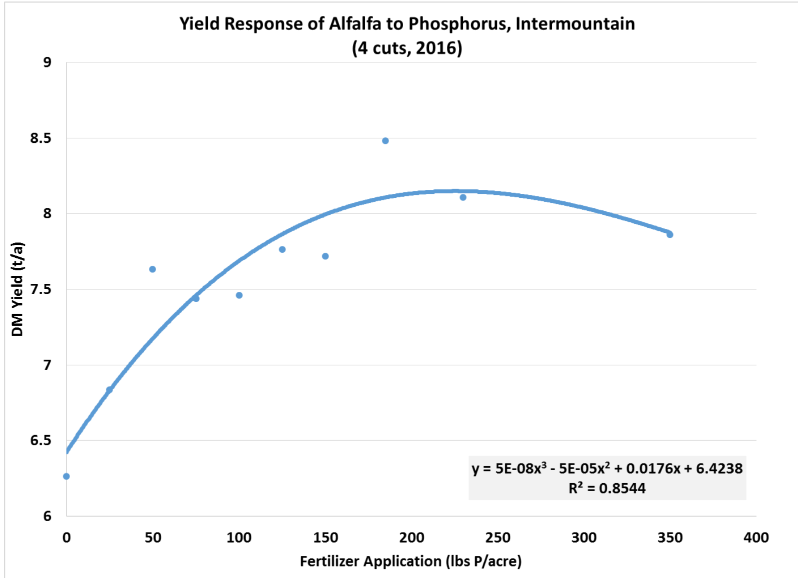

Figure 2. Yield response of alfalfa to phosphorus fertilizer (P_2O_5), Siskiyou Co., CA, 2016. First year data (Steve Orloff, UCCE Farm Advisor, Siskiyou County)

Response of alfalfa to P fertilization on P-depleted soils in the Sacramento Valley were also significant but less dramatic (Figure 3). This was a difficult, poorly drained clay-loam soil, so it had other limitations as well as low soil P levels. Both the sites for P experimentation were considered deficient soils (P< 5 ppm) using the Olsen test.

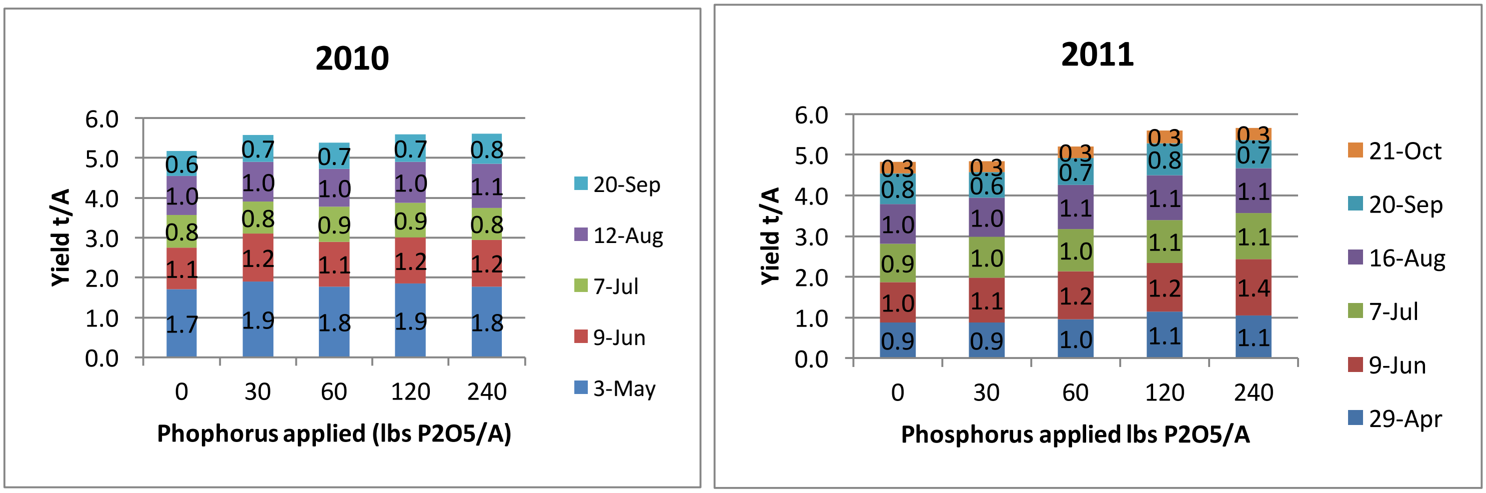

Figure3. Yield response of alfalfa to P application on a phosphorus deficient soil, Sacramento Valley, 2010-2011

Plant Sampling for Phosphorus and Potassium. The plant is often a better indicator of the nutrient supplying capabilities of a soil due to variations in rooting depth, the nutrient supplying characteristics of specific soils, and the limitations of soil sampling regimes and lab extraction. Often, we don't understand the true root exploration of a soil (is it 2 feet or 4 feet – how many

Table 3. Interpretation of tissue test results for alfalfa production, as per recommendations given by Meyer et al., 2007 for samples taken at the 10% bloom stage.

		Plant Tissue Value			
Nutrient	Sample	Deficient	Marginal	Adequate	High
		------------------------------ppm------------------------------			
Phosphorus	Mid 3rd Stems	300-500	500-800	800-1500	>1500 ppm
		------------------------------%------------------------------			
Potassium	Mid 3rd Stems	0.40-.65	0.65-0.80	0.80-1.50	>1.5%

Adapted from: Meyer et al., 2007. Note: Growth Stage will affect concentrations, with immature plants having much higher concentrations.

effective root hairs are in each layer?), nor the ability of the soil to release nutrients. Therefore, soil sampling is only one (but an important) way to analyze nutrient limitations. Plant tissue sampling, utilizing either whole plants or portions of plants is an important way to test for P adequacy in a standing alfalfa crop (Table 3). We have found plant sampling of either whole plants or plant portions to be diagnostic of P deficiencies (Figure 4) but threshold levels are very different for the different plant parts and at different stages – thus care should be taken to utilized thresholds for adequacy that are specific to either whole plants or plant parts.

Unfortunately, most alfalfa growers do not perform tissue tests and many growers fertilize (or don't fertilize) based upon habit or fertilizer company recommendations with little idea of the actual nutrient status of the field. Thus, more practical ways of obtaining plant samples utilizing bales samples (already commonly taken from hay stacks) might be useful.

Bale Sampling. 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. If those same cored samples could also be used for nutrient management purposes, it would greatly simplify the process of tissue testing and encourage more careful nutrient management. Results from one such comparison is found in Figure 4. In this and other datasets, we've found r^2 values of greater than 75%, indicating a high degree of correlation between the two methods. Using analysis of bale samples, growers may be able to 'pick up' nutrient deficiencies that would otherwise go undetected. In addition to less work, bale sampling has the added feature of actually sampling more forage than would be possible with hand sampling for forage. Typically, in a 20-core sample, over 5,000 stems from a field might be represented, while in hand-cut samples, hundreds of stems might be represented.

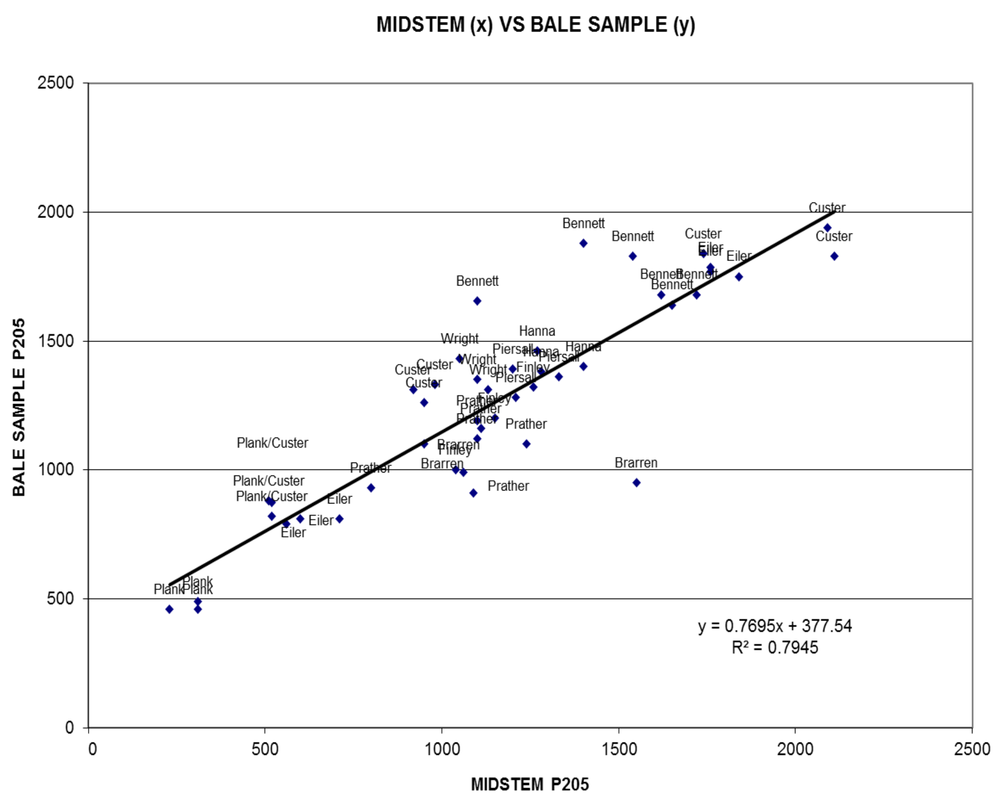

Figure 4. Phosphorus concentrations of Mid-stem samples compared with sampling from bales, data from a range of Intermountain alfalfa fields, 2007 (S.

Potassium (K) Response. Although K deficiencies are less common than P deficiencies, the crop will sill respond to K fertilization when deficiencies are present. We have seen K deficiencies especially on sandy soils. Alfalfa yield has responded dramatically to K rates at the Intermountain sites and in San Joaquin Valley sites (Figure 5).

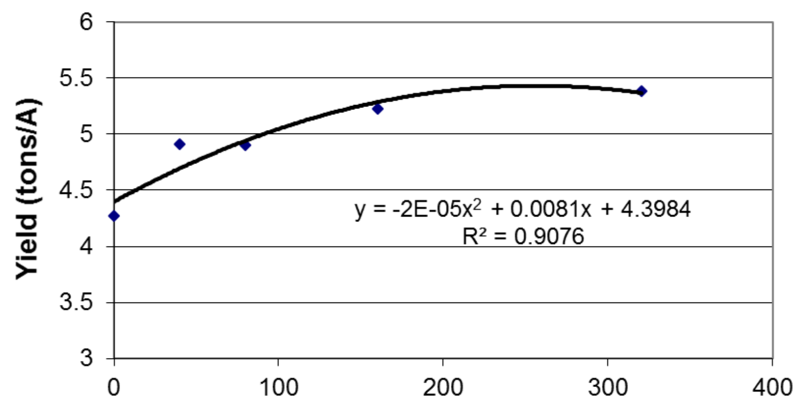

Figure 5. Typical potassium response, Intermountain soil, 2010.

Effect of Growth Stage and Sampling Method. Stage of growth and sampling method (whole plant, mid stems or top 15 cm) both have a large effect on concentration of P and K in alfalfa samples (Figure 6). Concentration of P and K in plants declines significantly with plant maturity, ranging from bud through 10% bloom stage. For P analysis, all three methods (whole plant, top 6" and stem) provide similar (parallel) results, but with different average concentrations for each method (Figure 6). Average levels of potassium concentrations were similar for whole plant and top 15 cm at all maturities, but concentrations in stems were much greater during early growth periods vs. late maturities (Figure 6).

CONCLUSIONS

For alfalfa, the importance of P and K fertilizers on deficient soils cannot be overemphasized. Due to high uptake levels, lack of a soil fertility management plan for alfalfa will lead to a 'mining' of soils, depletion of soil nutrient supply over time, and lower yields. We recommend a combination of preliminary P and K testing of soils and applications at stand establishment to meet the needs of approximately 2 years of crop growth, followed by plant sample monitoring to determine ongoing P needs of the crop for subsequent applications. Deficient soils require long-term strategies. Plant or bale sampling may be useful to determine relative status of soils, followed by more detailed monitoring. Stage of growth and sampling method should be considered when determining the threshold levels for whole plant and plant part tissue P and K concentrations. Sampling at earlier growth stages (vs. 10% bloom) is feasible, but different thresholds will be required. Alfalfa tissue testing protocols are simple to use and sufficiently accurate so that nutrient analysis can become a routine component of forage quality testing.

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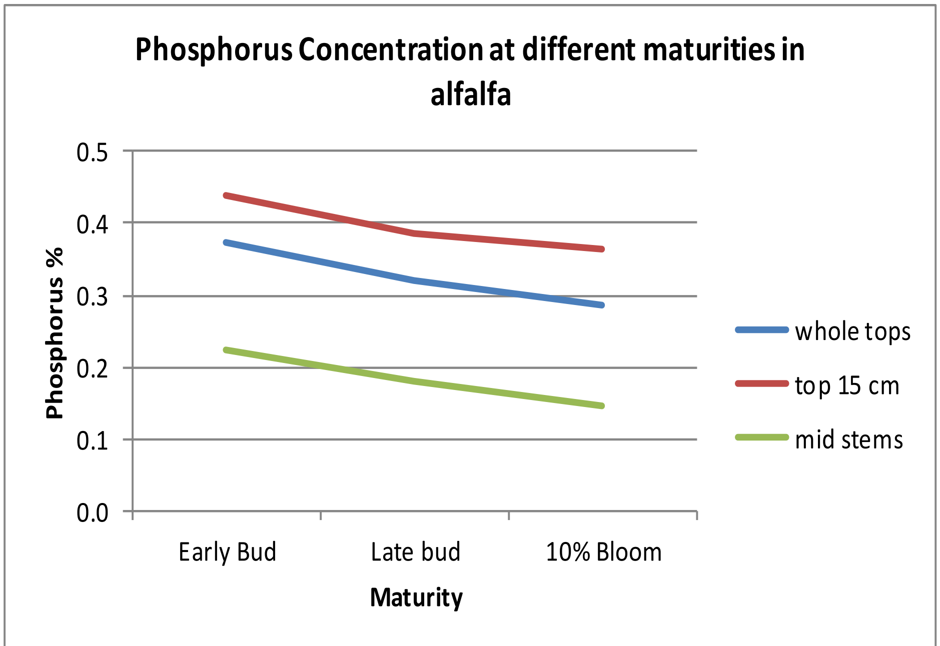

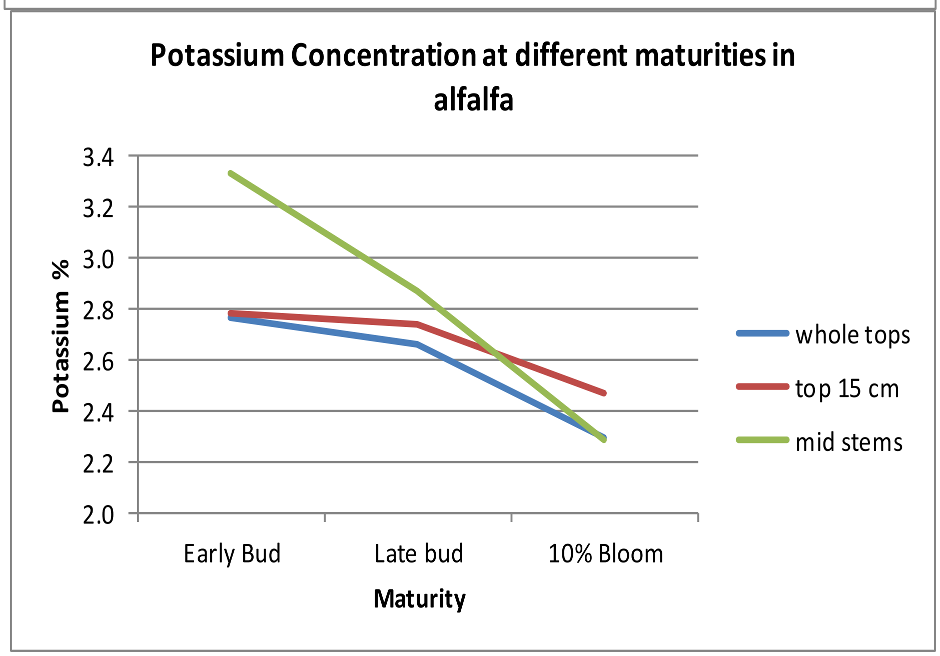

Figure 6. Influence of plant maturity on Phosphorus and Potassium concentrations in alfalfa, average of 10 farms, and all cuttings, 2010.

Potassium Management in Processing Tomato Production

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Keywords: threshold, K, K_2O, yield response

Summary

Processing tomato yield responses to supplemental applications of potassium have been demonstrated in field tests from 2011 to 2016 in the lower Sacramento Valley and upper Delta. Yield increases occurred primarily in soils with potassium levels below 200 ppm K using an ammonium acetate extraction method and, as a secondary indicator, not exceeding 2% of the cation exchange capacity. Composted poultry manure was initially used as a microbial stimulant, before understanding the value appeared primarily as a potassium source. The manure treatment was aimed to reduce premature vine senescence, a pervasive plant disorder common to the region. Early testing began with several UC Davis plant pathologists when pathogens were suspected as causal to vine decline. Subsequently, composted manure was compared and eventually substituted with manufactured potassium as the research shifted to be nutrient focused. For experimental field design simplicity and ease of application, after the initial years, most of the K treatments were preplant sidedressed using granular KCl.

Introduction

Composted animal manures have not been a common fertilizer source nor a nutrient supplement in conventional processing tomato production in California's Central Valley. Field studies were conducted which initially targeted treatments with potential to reduce premature vine senescence. Premature vine senescence common to Sacramento Valley processing tomato production occurs approximately 5 weeks before harvest with a decline in plant vigor. As vines collapse, fruit become sun-damaged and yield is reduced. While the cause of 'vine decline' has not been identified, a complex of soilborne pathogens was suspected. Initially, treatments included the application of biocides, fungicides and biologicals to suppress the pathogens, the addition of composted poultry manure to stimulate microbes and supplemental nutrients to support plant vigor and growth. While disease level was not affected, only the composted manure treatment increased fruit yield. Nutrient management became the focus of the research after the initial several years of field tests, while fungicides and biological materials were dropped in favor of applications of synthetic NPK fertilizers and synthetic potassium fertilizer sources, primarily KCl. The norm had been that only modest levels of K, if any, were part of the nutrient management program.

Materials and Methods

Two field tests per year from 2011 to 2013 were evaluated in commercial fields with a history of vine decline. Selected fields were irrigated by buried drip irrigation to facilitate applications of conventional fungicides and biological agents. The experimental design was a randomized complete block with 4 replications with each row representing a plot. Row lengths tended to be more than 1,000 feet long and most beds were on 5-foot centers. Materials over the years included conventional fungicides, biologicals, a preplant biocide, NPK fertilizers and composted poultry manure. Well-aged, composted poultry manure was applied on the bed top in a continuous pile on 100 feet of row ahead of shallow, springtime seedbed tillage. In later years, materials included potassium sulfate or potassium chloride sources and in one test, potassium carbonate. While tests remained primarily buried-drip irrigated, subsequent to the early tests, experimental setup switched to a more compact design with replications down the row and to ease application, K applied solely as a sidedress of granular KCl.

Yields were measured by hand harvest of a 15-foot subsection of row in 2011 and 2012. In subsequent years, mostly 100-foot plot lengths were mechanically harvested using the grower's commercial equipment with yields measured using a portable weigh-scale trailer. Fruit pH, °Brix and color were measured from a subsample of non-defect, red ripe fruit by the Processing Tomato Advisory Board.

Soil exchangeable K was measured by atomic emission spectrometry following ammonium acetate extraction (Thomas, 1982). The relative abundance of K was expressed as a percent of milliequivalents of base cations (Ca, Mg, Na and K) based on this extraction.

The field sites were used only in a single year while two of the earlier test fields were retested, but not positioned over the original test locations.

Results and Discussion

The presence of soilborne pathogens were initially thought to contribute to vine decline. The deficiency of plant nutrients was initially not widely perceived to be an issue. Commercially available products were selected in an attempt to suppress soilborne pathogens (fungicides and biological), to stimulate soil microbial populations (biologicals and composted manure) and to provide supplemental nutrients to support plant vigor and growth. All treatments were supplemental to the grower fertilizer program with generally robust nitrogen and phosphorus applications to support high production. Cultural practices beyond the application of treatments were those of the commercial growers including standard nutrient management.

Vine decline was observed to varying degrees in all sites; however, the incidence of recovery of pathogens in the laboratory (data not shown) was not affected by any treatment.

Yields were generally increased in the plots with composted chicken manure. Marketable yield increased in select fields. On a percentage basis, the yield increases were equivalent to 32%, 41% and 25% in 2011, 2012 and 2013, respectively. From those initial tests, a series of tests from 2014 to 2016 were conducted to establish a rough threshold level to help guide K management decisions.

In 2016, 3 tests were conducted, all in soils with less than 200 ppm K. Two of the tests had no yield response. A response occurred in an upper Delta site in a mineral soil with Egbert clay, with ~150 ppm K and 1.5% on the cation exchange. A positive linear yield response was measured with K applications from 50 to 800 pounds per acre of K_20 in a furrow irrigated field (Figure 3).

The results indicate yield increases to composted poultry manure applications are related to soils with potassium levels below 200 ppm and potassium levels not exceeding 2% of the cation exchange capacity (Figures 1 and 2).

Conclusion

Yields in fields with a history of vine decline were generally increased with the addition of composted manure. The contribution by composted poultry manure of supplemental nutrients, especially in soils with low potassium, was primary benefit of this practice. The studies did not demonstrate a direct link between improved yield and suppression of soilborne pathogens.

Yield response to potassium application may well be a combination of low available soil K, continued K mining without replenishing and higher tomato crop yield from improved cultivars and adoption of drip irrigation.

Acknowledgement

We thank the California Tomato Research Institute for funding support and the generous contribution of cooperating growers J.H. Meek and Sons, Timothy Farming & David Viguie Farming, Payne Farms, Harlan Family Ranch, Don Beeman Farms, Muller Ranches, Barrios Farms and a Delta-area farm. Additionally, potassium fertilizer was donated by Agriform. Composted poultry manure was supplied by UC Davis Ag Sustainability Institute's Russell Ranch project.

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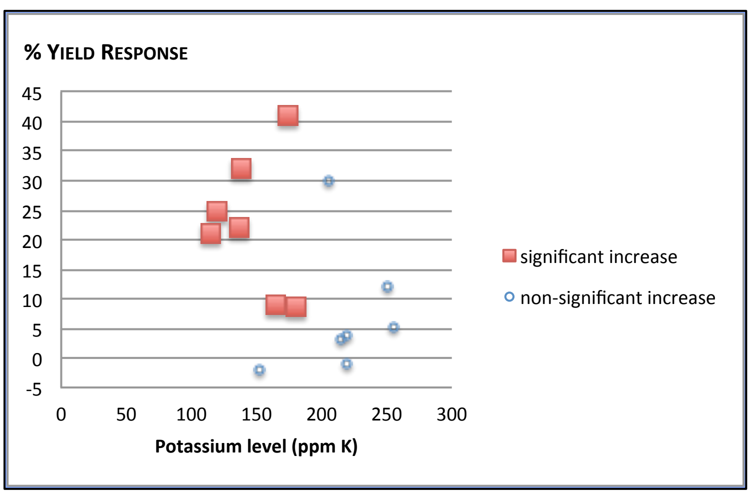

Figure 1. Influence of soil K level (in ppm) on processing tomato yield response to potassium fertilizer applications, Yolo-Solano, 2011-2015.

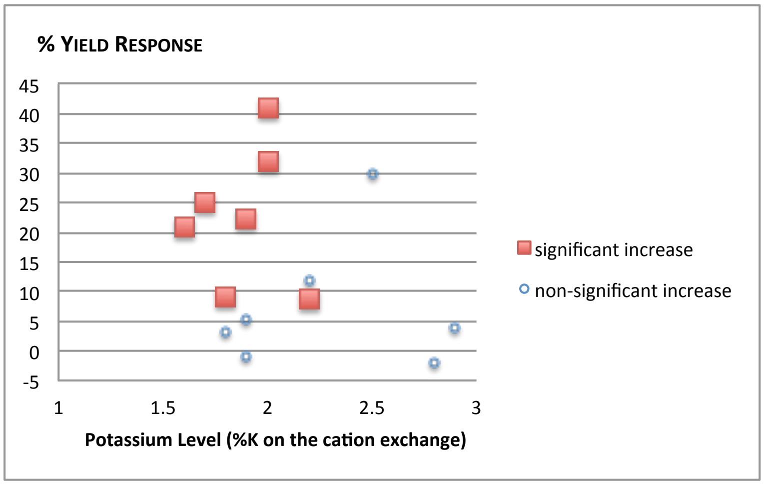

Figure 2. Influence of % K of the cation exchange capacity on processing tomato yield response to potassium fertilizer applications, Yolo-Solano, 2011-2015.

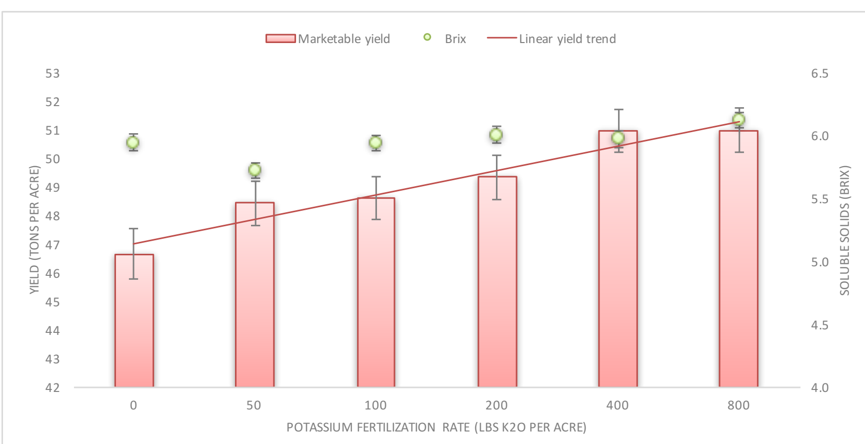

Figure 3. Effect of KCl application on processing tomato yield, Egbert clay, 150 ppm K, upper Delta, 2016.

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Session #2

Emerging Technologies for Improved Crop Management

Session Chairs:

Mark Lundy & Andre Biscaro

Applying Systems Thinking to Coherent Pest Management

Brian Speicher[1], John Mejia[1], PhD, Eric Wilcox[1], PhD, Ming Liu[1], PhD, Andrew Joros[1], Steve Sweet[1]

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Keywords: weather forecasting, decision support tools, remote sensing, pest management, collective intelligence

Systems Thinking and Forecast Model Coherence

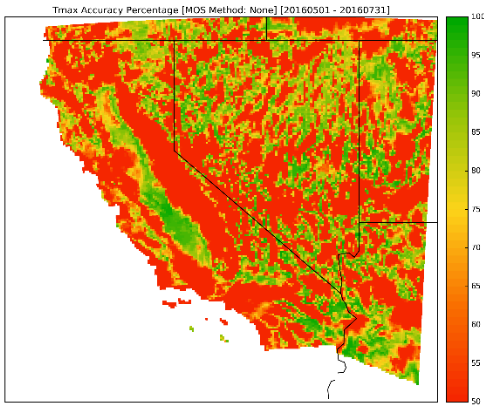
Forecasting research falls largely into two categories: efforts to architect better models to mimic reality, or to identify and eliminate bias in human forecasters. Considerable evidence exists to support the claim that generally, computational models produce more accurate forecasts, more consistently, than human experts. Yet, humans are more effective at processing unusual circumstances and data that lacks rules-based coherence and structure. (1)

An evolving area of forecasting research suggests that ensembles of human-machine forecast methods outperform both humans and modeling alone. These findings are particularly true in contexts with rapidly changing circumstances and variable patterns.(2) Extending this research, scientists at Desert Research Institute (DRI) have used weather forecasting as a modeling "regime" and as a basis for developing human-machine ensemble approaches to improving forecast accuracy.

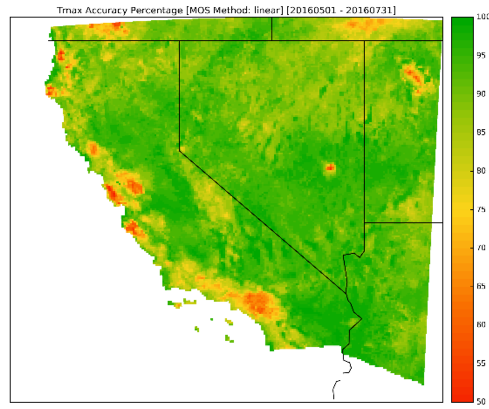
Specifically, weather forecasts are vulnerable to spatiotemporal distributions of error. DRI scientists gridded weather model forecast error into 1 km^2 parcels and parsed the error into components with identifiable sources. Forecast error can be correlated with the interaction of a number of factors existing at the boundary between the lower atmosphere and earth, including elevation, and land cover.

Once the interactions are quantified and applied to subsequent forecast models, the predictions better represent the *impact of weather*, which is not effectively incorporated into publically available weather forecasts. Specifically, weather impact observations inform the choice of ensembles of weather forecast bias correction methods to be assembled by human experts. The human-machine forecast approach then reduces overall forecast error. Example output below in Figure 1.

The aggregate effect is to improve forecast accuracy by encouraging *systems coherence* in forecasts. The forecast is assembled by a human-machine hybrid which contemplates the larger system more realistically - both the atmospheric modeling and the net impact of weather at the earth boundary. High performance computation enables machine forecast methods, and the rapid generation of forecast scenarios which can be assembled into ensembles of potential outcomes. Human experts can then apply sense-making processes that interpret model output, and optimize applied intelligence.



Spatial forecast accuracy without ensemble bias correction. Red indicates increasing forecast error.



Spatial forecast accuracy, ensemble bias corrected. Green indicates forecast improvement.

Figure 1. Maximum temperature forecasts before and after ensemble forecasting methods applied.

Applying Systems Thinking to Coherent Pest Management

Current pest management practice has the appearance of a hybrid human-machine model, somewhat skewed towards the traditions and practices of the human expert, but aided by only modest computation. As well, it is largely reliant upon *current* observation, and *current* estimates of risk, with limited ability to apply data-driven business intelligence with foresight and generate informed forecasts. Pest models are largely focused on insects, and dependent upon approximately 100+ degree-day algorithms to estimate risk, with little to no collateral information to enable coherence.

Profiting from lessons learned in the weather forecasting regime, DRI research scientists believe that the systems coherence of pest management in agriculture may be improved by a) shifting the proportional mix of human-machine participation, b) proactively delivering specific pest model forecasts of interest within reach of stakeholders, c) capturing fieldwalk scout observations as ground truth for forecast validation, and d) simultaneously ingesting data from embedded sensor arrays in fields to gain a panoramic view of conditions coincident with insect and disease observations made on fieldwalks. This final element is intended to enable the generation of new and improved insect and disease models arising from ensembles of data interrogated by machine learning exploration.

The theory is animated through an integrated software suite developed by DRI researchers. The low-touch, web-based module, called **ForecastView™**, allows users to locate properties and draw boundaries around their fields, identify crops, detail planting information, and choose pests of concern for which alerts are sent to estimate current, 3-day, and 7 day pest risk. It serves as a command and control platform enabling the rapid, real time overview of field status and fieldwalk observations in any location. The companion app, **FieldScout™** automatically syncs with ForecastView, downloading all user and field information. The app is the field walk companion, and allows 8 categories of observations during fieldwalks. With an observation being completed, a GeoPin drops onto the precise location of the observation documenting the details and metadata of the circumstance for follow-up.

A third layer of intelligence gathering enables the concurrent ingestion of data from field sensors, which promotes the machine learning exploration of coincident circumstances. The schematic in Figure 2 illustrates the feedback loops created to encourage a *pest management systems coherence*.

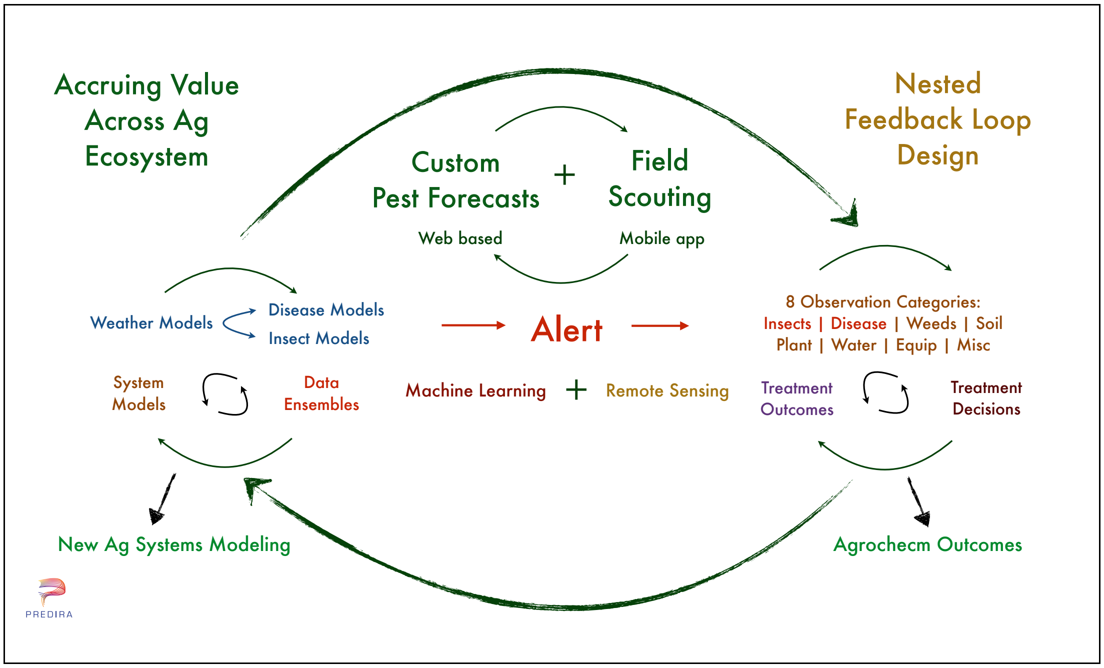


Figure 2. Illustrates the feedback loops created to encourage a pest management systems coherence.

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The Satellite Irrigation Management Support (SIMS) System: Applications of Satellite Data to Support Improvements in Irrigation Management in California

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Keywords: Irrigation management, remote sensing, evapotranspiration, decision support tool

In California and other agricultural regions around the world, threats to agricultural water supplies due to drought, groundwater depletion, population growth, and increasing variability in weather conditions are creating the need for tools to advance agricultural water use efficiency and support sustainable groundwater management. Satellite mapping of evapotranspiration (ET) from irrigated lands can provide agricultural producers and water resource managers with information that can be used to both optimize water application and improve estimates of groundwater withdrawals for irrigation. Satellite-based mapping offers a cost-effective means of monitoring ET over large areas, and various approaches are available (Gonzalez-Dugo et al., 2009; Anderson et al., 2012). We here describe the Satellite Irrigation Management Support (SIMS) system for ET mapping over agricultural regions in California, including important lessons learned that can be applied to accelerate development of other remote-sensing based tools for agriculture.

For irrigation management, the integration of satellite data and surface sensor networks to provide timely delivery of information on agricultural crop water requirements has the potential to make irrigation scheduling more practical, convenient, and accurate. Developed through a partnership between NASA, California State University Monterey Bay (CSUMB) and the California Department of Water Resources (CDWR), the SIMS framework integrates satellite data with information from the CDWR California Irrigation Management Information System (CIMIS) to map crop canopy development and key measures of crop water requirements at the scale of individual fields. SIMS data products are produced at a spatial scale of 30m x 30m (0.25 acres) and include the normalized difference vegetation index (NDVI), crop fractional cover (F_c), basal crop coefficients (K_{cb}) and basal crop evapotranspiration (ET_{cb}). NDVI, F_c and K_{cb} data are updated with each satellite overpass (currently every eight days), and ET_{cb} data are updated daily through integration of reference evapotranspiration (ET_O) data from CIMIS. Information is distributed to agricultural producers and water managers via a web-based interface and web data services. SIMS also provides an application programming interface (API) that facilitates integration with other irrigation decision support tools, such as the IrriQuest on-farm water use efficiency calculator, and CropManage, an irrigation and nutrient scheduling application developed by the University of California Cooperative Extension. Use of these tools also facilitates calculation of total crop evapotranspiration (ET_c) and irrigation system run-times.

SIMS (Melton et al., 2012) relies on reflectance-based methods for estimating ET_{cb} from satellite data via a crop coefficient approach. SIMS converts satellite NDVI (a spectral indicator of vegetation relative density and condition) to F_c based on past studies conducted by USDA in collaboration with NASA (Johnson & Trout, 2012; Trout et al., 2008), which found robust relationships across a range of different crop types and canopy architectures. SIMS combines F_c and estimated canopy height (h) to derive a density coefficient (K_d), which is then combined with a stomatal control factor (F_r) to calculate a crop-specific K_{cb} based on equations described in Allen & Pereira (2009). SIMS also ingests data from CIMIS, which produces daily maps of ET_O for California on a 2km statewide grid (Hart et al., 2009). Combining SIMS crop-coefficient data with CIMIS ET_O data facilitates daily estimation of ET_{cb} following the FAO-56 approach. Strengths of this approach include estimation of irrigation requirements under well-watered conditions, full automation, and ability to integrate data from multiple satellites to increase the number of available observations. Limitations include underestimation of soil evaporation and limited ability to detect short-term or intermittent deficit irrigation. The SIMS archive currently contains data from 2010-present for most of the state's irrigated lands.

Accuracy assessments conducted in commercial fields for more than a dozen crop types to date have shown that SIMS seasonal ET_{cb} estimates are within 11% mean absolute error (MAE) for ET_c of well-watered crops, and within 15% MAE vs. ET_c across all crop types studied. Use of a soil water balance model to correct for soil evaporation and crop water stress reduces this error to less than 8% MAE across all crop types studied to date, relative to field measurements of ET_c. On a daily timestep, MAE is 0.4 mm/day to 0.8 mm/day for well-watered crops including almonds, walnuts, peaches and various field crops, and 0.5 mm/day to 1.25 mm/day for deficit irrigated crops including wine grapes and raisin grapes.

Field trials conducted using CropManage and SIMS have shown that these tools can be used to sustain yields while improving water use efficiency and nutrient management. To date, irrigation trials have been conducted using a randomized block design with replicated treatments for several crops. Results for head lettuce and broccoli demonstrated reductions in applied water of 21% to 40% with no significant difference in crop yields or crop quality (Johnson et al., 2016). Preliminary results from trials in leaf lettuce (Cahn et al., 2017), cabbage and strawberries have demonstrated similar reductions in applied water while sustaining yields. Additional measurements collected during these trials have shown that ET-based irrigation management can also have important benefits for reducing nitrate leaching during the period of crop production. While gains in on-farm water use efficiency are important, we also recognize that there are a wide range of irrigation strategies that are currently utilized, and that many growers are already highly efficient in managing water. In addition, there are times when application of irrigation in excess of ET_c is important for salinity management, and can also support groundwater recharge or other beneficial uses. However, even when maximizing irrigation efficiency is not the primary goal of the irrigator, ET_c data can be used as a consistent reference to plan and evaluate an irrigation management strategy.

Agricultural applications that can be supported by SIMS include irrigation scheduling and management, calculation of water use efficiency metrics, compliance monitoring for water transfer agreements, and use in development and evaluation of sustainable groundwater management plans. The SIMS team is currently working to transition SIMS to sustained operations at CDWR using cloud computing resources. Once the system is fully operational, we anticipate that California growers will be able to more easily access and routinely use satellite data as a component of their irrigation management strategy, supporting continued advances in on-farm water use efficiency while sustaining crop yields and quality.

Support for this work has been provided by the NASA Applied Sciences Program, the CSU Agricultural Research Institute, USDA NIFA, the California Department of Food and Agriculture, and the California Department of Water Resources.

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Improving Irrigation Management with Remotely Sensed Images from Satellite and Drones

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Keywords: Remote sensing, drones, UAV, irrigation management, evapotranspiration

Irrigation accounts for 80% of human freshwater consumption, and most of it returns to the atmosphere through evapotranspiration (ET). Given the challenges of already-stressed water resources and groundwater regulation in California, timely information on evapotranspiration (ET), a dominant component of crop consumptive water use, with known uncertainty is critical for growers to tailor irrigation management based on in-field spatial variability and in-season variation. We developed a semi-empirical Priestley-Taylor (PT) approach to estimate daily ET at a 30m resolution in California's agricultural lands. Daily net radiation was estimated mostly from Landsat satellite multispectral and thermal observations. MODIS Terra and Aqua land surface temperature (LST) products were combined to improve the outgoing longwave radiation estimate. The partitioning of available energy to latent heat, represented by the PT coefficient, was parameterized as a function of leaf area index and normalized moisture index derived from Landsat imagery. We optimized the PT coefficients for each crop type with available ET measurements from eddy covariance towers or surface renewal stations for seven crop types (alfalfa, almond, citrus, corn, pasture, pistachio, and rice) in California. A generalized PT optimization was also done for the rest of crops where no field data was available.

Good agreement was found between satellite-based estimates and field measurements of net radiation with a R^2 of 0.83 and RMSE of 26.2 Wm^{-2}. Daily ET estimates from the PT approach optimized with 70% of the field data agreed well with the measured ET ($R^2 = 0.84$), and the RMSE of the estimated daily ET was less than 1.3 mm/day during Landsat overpassing dates and 1.5 mm/day when comparing with the 30% of field data. We applied the calibrated algorithm to the Sacramento-San Joaquin Delta region to map ET for the 2015 and 2016 water year. It captured the seasonal dynamics and spatial distribution of ET well in the region. Our study demonstrated that the semi-empirical PT approach, calibrated with ground measurements and driven by satellite observations, shows great promise for consistent ET mapping across diverse crop types. This continuous monitoring of crop consumptive water will help growers to tailor irrigation management at the field scale and inform decision makers to adaptively manage water at a larger scale.

We also tested the capability of UAV-based multispectral and thermal aerial imaging in crop ET mapping at 1meter resolution. Five flights were deployed to match Landsat 8 satellite overpasses during the 2016 irrigation season in ~3.5 hectares blocks of alfalfa, pasture and corn in

Staten Island in the Sacramento-San Joaquin Delta. Aerial imagery from both Micasense RedEdge 5-band camera and ICI 9640 thermal camera were collected. We used another ET approach, Mapping EvapoTranspiration using high Resolution and Internalized Calibration (METRIC) to estimate instantaneous and daily ET. Our results showed that, when aggregated to the Landsat scale, mean daily ET estimates from UAV observations are similar to those derived from Landsat-8 satellite observations. However, in all three crops, given its higher spatial resolution (1 and 0.05 m pixel), UAV estimates captured a significant higher spatial variability and wider range of values for fractions of reference ET (ETrF), and consequently ET. The UAV-based imaging proved to be another important emerging technology for crop consumptive water use monitoring, due to its easy deployment and high spatial and potentially temporal resolution.

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Session #3

Pest Management

Session Chairs:

Rachel Naegele and Margaret Ellis

UC IPM Updates

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Keywords: integrated pest management, online training, decision support tool, bee pesticide toxicity

Introduction

The University of California Statewide IPM Program (UC IPM) helps residents, growers, land managers, community leaders, and other professional pest managers prevent and solve pest problems with the least unintended impacts on people and their surroundings. The program draws on expertise of University of California (UC) scientists to develop and distribute UC's best information on managing pests using safe and effective techniques and strategies that protect people and the environment. These techniques and strategies are the basis of integrated pest management, or IPM. UC IPM works through Cooperative Extension to deliver information to clients in every California county. Printed publications and online information and tools provide a wealth of how-to information about identifying and managing pests

Pest Management Guidelines updates

The ***UC IPM Pest Management Guidelines*** are the University of California's official guidelines for managing agricultural pests in California (ipm.ucanr.edu/PMG/crops-agriculture.html). The *UC IPM Pest Management Guidelines* includes information to manage pest insects and mites, nematodes, weeds, and plant diseases. The publication series includes practical recommendations for pest control, including nonchemical methods and pesticides, and how to use these tactics in an effective, integrated program. With the year-round IPM programs, the guidelines describe a multidisciplinary, monitoring-based IPM program. Additionally, the guidelines include crop-specific tables such as a comparison of relative toxicities of pesticides to natural enemies.

Improvements to the author, peer review and production processes are increasing the number of updates and revisions to the *Pest Management Guidelines*. Our crop leadership teams help focus the direction and content. We are currently working to make the *Pest Management Guidelines* mobile-friendly.

New tools

The agricultural ***Decision-Support Tool*** (ipm.ucanr.edu/decisionsupport) was a deliverable for a California Department of Pesticide Regulation funded project to document the critical uses of chlorpyrifos in four key crops. Because of the amount of information in the *Pest Management Guidelines*, it can be difficult to navigate, compare, and assess information for multiple arthropod pests. With the tool, multiple pests and their pest management practices can be compared for their spectrum of activity, and pesticides can be reviewed for their movement into water bodies and risk of harm to human health, role in resistance management, and impact on honey bees and natural enemies. Using the tool results in a report linking to detailed online information that includes pesticide safety and mitigation information. The tool provides an overview of IPM options for alfalfa, almond, citrus, and cotton insect pests where chlorpyrifos was listed as an option to use. We plan to expand the tool to include lettuce, strawberry, pistachio, and walnuts. Additionally, we want to explore with key UC weed and disease experts how to include the other pest disciplines such as diseases and weeds.

Information about the harm of pesticides to honey bees can be found in the new ***Bee Precautions Pesticide Ratings*** (ipm.ucanr.edu/beeprecaution). The purpose of this tools is to help users make an informed decision about how to protect bees when choosing or applying pesticides. Pesticides can harm bees if they are applied or allowed to drift to plants that are flowering. The bee precaution pesticide ratings cover the active ingredients for acaricides (miticides), bactericides, fungicides, herbicides and insecticides. Ratings fall into three categories. Red, or rated I, pesticides should not be applied or allowed to drift to plants that are flowering. Plants include the crop AND nearby weeds. Yellow, or rated II, pesticides should not be applied or allowed to drift to plants that are flowering, except when the application is made between sunset and midnight if allowed by the pesticide label and regulations. Finally, green, or rated III, pesticides have no bee precautions, except when required by the pesticide label or regulations. Pesticide users must follow the product directions for handling and use and take at least the minimum precautions required by the pesticide label and regulations.

The ***Herbicide Symptoms*** (herbicidesymptoms.ipm.ucanr.edu) online database and educational materials can be used to help diagnose and assess the damaging effects of herbicide symptoms. Herbicide symptoms can look very similar to symptoms caused by diseases or nutrient deficiencies, resulting in unnecessary pesticide and fertilizer applications. Unintended injury can occur through herbicide residue left in the soil or spray tank, overapplication, or drift. Other online resources with herbicide symptoms exist, but cover only a few crops. This database is the largest and most comprehensive repository of herbicide symptom pictures available.

New and Revised Publications

A card set, ***Understanding Pesticide Labels for Making Proper Applications***, helps users understand pesticide labels. The primary way pesticide applicators can assure that they make proper applications and avoid illegal pesticide residues is to follow the pesticide label. The card set is in English and Spanish and PDFs can be downloaded online (ipm.ucanr.edu/IPMPROJECT/freepublications.html). Intended for pesticide handlers, applicators, safety trainers, and pest control advisers, the cards explain when to read the label, describe what kind of information can be found in each section of a pesticide label, and point out specific instruction areas so that applicators can apply pesticides safely and avoid illegal pesticide residues.

The newly revised third edition of ***The Safe and Effective Use of Pesticides*** provides detailed information for training employees to select, use, handle, store, and dispose of pesticides safely and properly. Newly updated content covers recent changes to federal and state pesticide laws, including the federal Worker Protection Standard. Emphasis is placed on prevention of groundwater contamination, protection of endangered species and wildlife, and reduction of environmental impact. This comprehensive publication is the recommended study guide for the California Department of Pesticide Regulation's pest control adviser and pesticide applicator examinations. It is an essential reference and study tool that applies to agricultural, structural, landscape maintenance, greenhouse and nursery, right-of-way, forest, aquatic, demonstration and research, public health, and regulatory pesticide-use situations. *The Safe and Effective Use of Pesticides* is Volume 1 of the Pesticide Application Compendium (ipm.ucanr.edu/IPMPROJECT/pesttrain.html#COMPENDIUM). This series was written for professionals trying to meet California's tough applicator licensing requirements.

New Videos

View our videos and learn to identify pests or how to monitor for them.

- ***Identification of Parasitized Alfalfa Caterpillars***
  https://www.youtube.com/watch?v=8_9zpYyY7Ig&feature=youtu.be (2:37)
- ***Sampling with a Sweep Net in Alfalfa***
  https://www.youtube.com/watch?v=hVDgA7DWh0c (1:48)
- ***Aphid Identification and Monitoring in Alfalfa***
  https://www.youtube.com/watch?v=K1a355JO79c&feature=youtu.be (5:22)
- ***How to Monitor for Aphids in Plum and Prune***
  https://www.youtube.com/watch?v=kbm55xeQlWs (4:00)
- ***Detecting Asian Citrus Psyllid***
  https://www.youtube.com/watch?v=QhQXL4bwnXI (1:00)
- ***Brown Marmorated Stink Bug Identification***
  https://www.youtube.com/watch?v=EHhtss8E7xM (2:59)
- ***How to Monitor for Mites in Peach and Nectarine***
  https://www.youtube.com/watch?v=Wg_IAqZiSAM (3:12)
- ***How to Distinguish Phytophthora Root Rot from Bacterial Canker***
  https://www.youtube.com/watch?v=Wg_IAqZiSAM (2:47)
- ***How to Monitor Shoot Strikes in Peach and Nectarine***
  https://www.youtube.com/watch?v=hfsqSVOG-zE (3:03)
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  https://www.youtube.com/watch?v=l0aP5AiHtfk (3:42)

New Online training

View these online trainings and others on our online training webpage (http://ipm.ucanr.edu/training/).

The ***Pesticide Application Equipment and Calibration*** course provides practical information on calibrating various types of application equipment to make sure you apply the correct amount of pesticide to a treatment area. Continuing education units: 1.5 hours "Other" From the Department of Pesticide Regulation; 1.5 hours “Technical” towards Branches 2 & 3 from Structural Pest Control Board—meets the continuing education category of Pesticide Use and Application for licensed applicators. The course is free to enroll.

The ***Pesticide Resistance*** course provides information on pesticide resistance in fungi, insects, and weeds and discusses practical ways of managing or delaying resistance. Continuing education units: 2.0 hours “Other” from the Department of Pesticide Regulation. The course is free to enroll.

The ***Proper Pesticide Use to Avoid Illegal Residues*** course provides information on pesticide residues, monitoring, tolerances, and risk assessment, and focuses on important sections of the pesticide label, presenting real-life scenarios where the most important factors leading to illegal residues are identified. Continuing education units: 2.0 hours "Pesticide Laws & Regulations" from the Department of Pesticide Regulation; 2 credits from the Arizona Department of Agriculture. The course is $40 to enroll. If you do not need continuing education units, view the content of this course on YouTube for free (https://www.youtube.com/playlist?list=PLo3rG4iqv4gEHrtixdZnOipGoR-pBWv

Etiology and Management of Trunk and Scaffold Canker Diseases of Almond in California

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Keywords: Almond, canker, fungal pathogens, *Botryosphaeriaceae, Ceratocystis, scaffold, trunk*

Introduction

Trunk and scaffold canker diseases (TSCD) of almond can cause significant yield and tree losses within orchards, while also reducing orchard life spans. TSCD often go unnoticed during the early stages of infection and symptoms appear more visible as trees age. Common symptoms of TSCD include discoloration of vascular tissues, wood necrosis and extensive gumming. Dieback of scaffold branches can occur and eventually the whole tree may die. In California, several pathogens are known to cause cankers in trunks and scaffold branches of almond. Among them *Ceratocystis fimbriata* has been widely studied as the causal agent of Ceratocystis canker. While this disease is generally associated with shaker damage and bark injuries at harvest, *C. fimbriata* is also capable of infecting branches from fresh pruning wound made during late fall and winter (Teviotdale and Harper, 1996). In recent years, several botryosphaeriaceous fungi have been associated with band canker, an unusual, non-chronic canker disease affecting the trunk of rather young trees. The same pathogens can also produce perennial cankers that can sometimes kill trees (Inderbitzin et al., 2010). *Eutypa lata* the causal agent of Eutypa dieback of stone fruit has also been recovered sporadically in California from cankers in trunk and scaffold branches, but the extent and significance of this disease in almond orchards is currently unknown. Additional pathogens causing perennial cankers in trunks and scaffolds have included *Phytophthora* spp., a group of soilborne pathogens of almond. Additional report of TSCD in almond outside of the United States have included Leucostoma (Cytospora) canker caused by *Leucostoma persoonii* as well as Collophora canker caused by *Collophora hispanica* (Arzanlou and Dokhanchi, 2013; Gramaje et al., 2012; Arzanlou et al., 2016).

Field diagnosis of TSCD is done commonly by pest control advisers and farm advisers based on symptoms observations. Previous reports have indeed suggested distinctive symptoms among some of the TSC diseases. These include differences in canker morphology as well as in the outer distribution of resin exudate or gumballs. Nevertheless, the main causes of TSCD and almond tree death in California is still uncertain and field diagnosis of TSCD remains challenging as symptoms delineation among these diseases is not clear. The relative importance of these different infectious diseases and their respective distribution in California are unknown. Management strategies against TSCD rely for the most part on remedial surgery, cultural and prophylactic practices including removal of trees. Accurate disease diagnosis is therefore essential to the implementation of appropriate control methods against TSCD. The aim of the proposed research is to improve diagnosis and management strategies of TSCD by gaining new knowledge on the etiology, biology and symptomology of TSCD diseases in California.

Material and methods

Survey and fungal isolation. During 2015 and 2016, samples were obtained by visiting symptomatic almond orchards or by submission to the laboratory for diagnostic services. Symptoms included dieback, gummosis, girdling, resinosis and vascular discoloration on almond branches, scaffolds or trunks. Symptom differences were annotated for the different causal agents. Trunks and scaffolds displaying symptoms were sampled by removing bark and branches to reveal the inner wood revealing the canker. In the laboratory, wood samples were surface disinfected in of 2% sodium hyphochlorite solution for 2-3 minutes and rinsed twice with sterile distilled water. Samples were processed using several methods to assay for a wide range of potential causal agents. This included plating necrotic wood pieces on acidified potato dextrose agar (APDA) for the isolation of true fungi, on PARP medium for the isolation of *Phytophthora* spp. and the use of humid crispers for the isolation of *Ceratocystis fimbriata.* Pure cultures were obtained by transferring colonies onto APDA or PARP medium. In the case of *Ceratocystis fimbriata*, ascospore masses produced on perithecia growing from incubated wood pieces were transferred onto APDA.

Molecular identification. Fungal mycelium in pure cultures on PDA was used for DNA extraction with the FastDNA™ SPIN KIT (MP Biomedicals, Santa Ana, CA, USA) following the manufacturer instructions. Amplification and sequencing were first performed with the internal transcribed spacer region (ITS) of the rDNA to determine our isolates to species. In addition to the ITS region, additional loci were sequenced to enhance phylogenetic resolution and included: translation elongation factor (TEF1-α), beta-tubulin (BT), and Glyceraldehyde 3-phosphate dehydrogenase (GAPDH). All loci were amplified using PCR conditions previously described and DNA was sequenced using Sanger sequencing technologies. Sequence identities were confirmed using GenBank BLASTn searches.

Pathogenicity trials. To determine pathogenicity, a trial on almond was set up in August 2016 to test the aggressiveness of 21 isolates representing the various TSCD associated fungi isolated during the survey. One-year-old potted 'Nonpareil' almond saplings were inoculated at the Kearney Agricultural Research and Extension (KARE) Center and maintained in a lath house. The central portion of the stem was inoculated by placing a 5-mm-diameter mycelium plug from a 7- to 10-day-old PDA culture in a wound made by a 5-mm-diameter cork borer. Wounds were sealed with petroleum jelly to maintain moisture during the incubation period and protected with Parafilm. Fungal treatments were compared to a control treatment inoculated with non-inoculated agar plugs. The experiment was set up in a randomized complete block design with seven replicates. Trees were examined after 6-weeks post-inoculation to assess length of vascular discoloration (lesions) and percent fungal recovery from disease tissues.

Results and discussion

During 2015 and 2016, we visited and sampled approximately 70 almond orchards throughout the Central Valley, spanning 15 counties with symptoms of almond TSCD. Approximately 300 isolates were isolated from cankers and were characterized using morphological and molecular methods. To date, Botryosphaeriaceae cankers and Ceratocystis canker were the most commonly encountered canker diseases of almond. Other prevalent canker diseases found in almond included Phytophthora canker, Eutypa canker, and Cytospora canker. Cankers caused by *Diaporthe* (*Phomopsis*) spp. and *Collophora* spp. were also identified in this survey, but did not appear to be as widespread. Ceratocystis cankers were found in all the counties surveyed and in both young and mature trees. Ceratocystis canker of almond has not been investigated since the emergence of modern techniques in molecular biology and the genetic diversity and population structure of *C. fimbriatra* is currently being reexamined. Questions such as the origin of the inoculum of Ceratocystis canker and the role played by mechanized harvesting equipment in spreading the pathogen remain elusive. Botryosphaeriaceae cankers were associated with pruning wounds and prevalent in 3-4th leaf orchards in the Sacramento Valley. *Neoscytalidium dimidiatum*, also in the Botryosphaeriaceae, was associated with pruning wounds and tree crotch infections in 3-4th leaf almond orchards in Madera, Merced, Fresno and Kern Counties. This fungus was recently reported in California on walnut and is found on table grape, citrus and figs in the state. It has emerged within the last few years as the state has experienced a severe drought, suggesting that drought conditions and the rising of temperatures may be conducive to the pathogens fitness in tree crops. Cytospora cankers were also detected near pruning wounds and found in 3-4th leaf orchards and older in Merced, Fresno and Stanislaus counties. To date we have recognized at least six different species in almond. Little work has been conducted on Cytospora cankers in almond but studies in sweet cherry in California have shown that *Cytospora* species constitute some of the most aggressive canker pathogens in this host (Trouillas et al. 2012). *Eutypa lata* was associated with pruning wounds and infections at the tree crotch in 3-4th leaf orchards. Infections at the crotch of the tree may be indicative of early infections during scaffold selection in an orchard. *Collophora hispanica* and *C. paarla* were associated with reddish-colored, circular branch cankers. Additionally, *Phytophthora cinnamomi* was isolated from second leaf almond trees in an orchard in Kern Co.

The pathogenicity test revealed that *Neofusicoccum arbuti* and *Neoscytalidium dimidiatum* were the most aggressive on almond. *Neofusicoccum arbuti* killed 20-60% of inoculated saplings. From the broad diversity of Botryosphaeriaceae species tested in this trial, we observed significant variation in their capacities to cause lesions in almond. *Cytospora* sp. K226 was aggressive causing large lesions and gumming at the point of inoculation. The other *Cytospora* species varied greatly in virulence. Other species (*C. fimbriata*, *E. lata*, *Phomopsis/Diaporthe* spp., and *Collophora* spp.) proved to be pathogenic on almond causing vascular discoloration, but not as aggressive compared to cankers caused by Botryosphaeriaceae species. The results of the pathogenicity test suggest that Botryosphaeriaceae cankers are the most devastating, especially on young trees.

Management of canker diseases rely for the most part on prevention as no chemical treatments can cure these diseases. Overall, canker diseases may be managed by avoiding bark injuries from mechanical shakers and avoiding pruning trees before or during rain events. Management of canker diseases may rely on remedial surgery (removal of the cankered area), however, cankers are generally difficult to remove and may require multiple surgeries over several years before all the infected tissue is removed. Removal of infected tree parts and dead trees will reduce inoculum in the orchard. When whole, diseased trees are removed, the stumps should also be removed as the bark of stumps can be covered with the pathogen fruiting structures and thus serve as sources of inoculum. Adjusting sprinkler irrigation so that tree trunks and tree crotches are not wetted helps reduce the incidence of canker diseases. Proper primary scaffold selection and avoiding stress are the most effective preventive measure to reduce risks of infection by canker pathogens.

Future work will target management of almond canker diseases using pruning wound protectants as TSCD pathogens are primarily associated with pruning wounds, which serve as the main infection court. Pruning wound protection should prevent fungal entry and infection. Several pruning wound protection products to be tested include chemical fungicides, biological control agents (*Trichoderma* species) and wound sealants (paint and wax). Protection of pruning wounds combined with prophylactic measures including cultural practices should help mitigate the impact of canker diseases of almond in California.

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Session #4

Site-Specific Management

Session Chairs:

Andre Biscaro & Mark Lundy

A Global View of Precision Agriculture: Opportunities for California

Steve Phillips
International Plant Nutrition Institute

Keywords: precision agriculture, technology, plant nutrition, variable-rate, spatial, temporal variability

Precision agriculture (PA) tools, technologies, and information management strategies are becoming mainstream in many regions of the world. Several technologies such as automated guidance, yield monitoring, and georeferenced soil sampling are no longer considered premium services, but are standard offerings from many agricultural providers. Information needed for farm management is also more accessible and delivered faster through mobile device technology than ever before. Precision agriculture has been identified as a key component in developing the high-production, high-efficiency systems needed to meet the food demands of the future. For the past two decades, Purdue University has conducted a survey of agriculture service providers in the Midwest USA regarding the use of PA. Those participating in the survey were asked about customer adoption of PA, how PA is used at the dealership, and the profitability and expected future investment in PA. The history of the survey begins when GPS was first used to guide soil sampling, apply fertilizers, and create yield maps; which are now technologies ubiquitous on US farms. Adoption of these types of technologies that don't depend on site-specific information to extract value has been rapid and steady, while others that require agronomic calibration or some level of data management such as remote sensing, soil management zone delineation, and using yield maps to characterize and understand field variability has been slower and a much greater challenge than many would have predicted two decades ago. Despite the lower costs and much greater capacity to store data compared to twenty years ago, the information side of PA also continues to struggle in demonstrating value. The objective of this presentation is to evaluate trends in PA use around the world and to discuss current industry and academic efforts to overcome existing barriers to adoption and how these efforts might affect CA agriculture.

Optimizing irrigation scheduling with limited water using the iCrop decision support tool

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Keywords: Decision support tool, irrigation management, crop modeling, DSSAT

Optimizing irrigation scheduling with limited water under erratic weather is not trivial and requires a systems approach to understanding crop yield response to water. Therefore, producers and crop consultants need dynamic/interactive decision support tools that integrate the entire farming system including soil (S), weather (E, environment), genetics (G), and crop production practices (M, management; e.g., irrigation and fertility management practices). The focus of my presentation will be to demonstrate how a new and innovative model-driven decision support tool called iCrop can be used to optimize irrigation scheduling on a field-by-field basis in California. Behind iCrop is a calibrated and validated DSSAT-CSM model (Decision Support System for Agrotechnology Transfer Cropping Systems Model). iCrop is linked to CIMIS (California Irrigation Management Information System) and automatically accesses weather data. iCrop is also linked to soil databases allowing automated preparation of input files for the crop simulation model. I will demonstrate how iCrop could be used to tactfully optimize in-season irrigation scheduling decisions by minimizing number of irrigation applications in wet years to normal weather years and increasing number of irrigations applications in drought years while optimizing yields. iCrop can also be used to strategically optimize crop-water allocation. iCrop shows the potential of going from complex models to usable decision support tools and how they can be used to enhance resource use efficiency.

Mapping Soil Variability to Inform Gypsum Application in a Commercial Tree Nut Setting – Challenges and Opportunities

Author: Curran Hughes, Manager of Strategy, The Wonderful Company

Keywords: soil mapping, precision agriculture, site-specific soil management, gypsum, soil salinity

A 2016 Goldman Sachs survey of U.S. agriculture found that the majority of growers applied too much nutrition on up to 40% of their fields and too little in weaker areas. While soil mapping as a platform for zonal management is a well-established technology, its adoption has for the most part lagged in orchard crops as well as at Wonderful Orchards.

In our experience, the slow technology adoption of soil mapping in many orchard crops is not due to the lack of science validating the technology and its potential benefits. Adoption is however impeded by operational hurdles associated with changing cultural practices in a commercial setting. In 2017, Wonderful Orchards sought to leverage soil mapping techniques to inform bulk gypsum applications and develop a workflow that could be scaled across a large operation.

In this presentation, Wonderful Orchards will provide a high-level overview of their progress after their first year of a multi-year project to better incorporate soil mapping as part of their crop management strategy. Although the team has not finalized trial results, they will discuss the workflow, operational challenges encountered with soil mapping, actions taken based on soil mapping data and opportunities to streamline soil mapping practices for large commercial operations.

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Session #5

Soil Biology & Soil Health

Session Chairs:

Karen Lowell, Daniel Geisseler,

and Eric Ellison

How much can soil organic matter realistically be increased with cropping management in California?

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Introduction

Soil organic carbon (SOC) is one of the most important characteristics of soils that results from the interplay of biogeochemical processes promoted through net primary producers, soil biomass and soil mineralogy. The stabilization of SOC with reactive minerals, particularly clays and short range order and metal oxide minerals, provides for a stable matrix that supports soil structure, increases moisture holding capacity and a source of nutrients for crops. The importance of SOC to support food and fiber production cannot be understated. The outcome of different management practices to support SOC sequestration with the aim of improving soil health and productivity and to mitigate carbon dioxide (CO_2) emissions from land use change and fossil C combustion has become a hot topic in both soil science and policy areas.

Since the Green Revolution and before, the intensity of cropping and soil management has increased considerably. The increase in agronomic management intensity has resulted in soil organic carbon (SOC) loss of up to 50% (Bebi and Brar 2009). Overall, fossil fuel use to support intensification and the long-term conversion of extensive areas of virgin land to agriculture have led to agriculture systems being net contributors to changing the atmospheric composition and climate (Falkowski et al., 2000).

Management to Sequester Carbon

The general consensus on the carbon (C) balance of agricultural land is that SOC loss has dominated as a result of agricultural intensification. The initial loss of SOC was attributed to the "plow effect" where soil disturbance from tillage exposed protected SOC, particularly occluded within aggregates. Other factors discussed or documented in the literature include, 1.) A reduction in crop species diversity, often a monoculture such as grain crops, that reduced the complexity of soil inputs 2.) a reduction in manure return as farmers specialized in crops and eliminated or reduced herd sizes, 3.) increased winter fallow as fertilizers reduced the need for cover crops, 4.) winter fallow lead to soil erosion, 5.) excess use of nitrogen (N) fertilizers that increased the mineralization of SOC, 6.) removal of crop residues for animal feed and fuel, resulting in less C inputs, and 7.) open field burning as a residue management practice. All of these and other factors contributed to considerable SOC losses from the plow layer of surface soils (0–30 cm) and in many cases deeper (Fig. 1).

The importance of SOC to soil productivity has long been recognized (Jenny 1941; Allison 1973). Numerous studies and observations have concluded that restoring SOC can increase crop yields (Lal 2007). Cropping and soil management practices such as reduced or no till, cover crops, diverse crop rotations, manure inputs, etc., can increase SOC (Qiao et al. 2014; Lal 2004; Lal 2010). However, in a study on arable crops in Europe, restoring SOC did not necessarily increase crop yields, given sufficient nutrients to support productivity from fertilizer inputs (Hijbeek et al. 2017). The general consensus among soil scientists is that increasing SOC is an important component of increasing soil health and in reversing the global warming potential of agricultural systems.

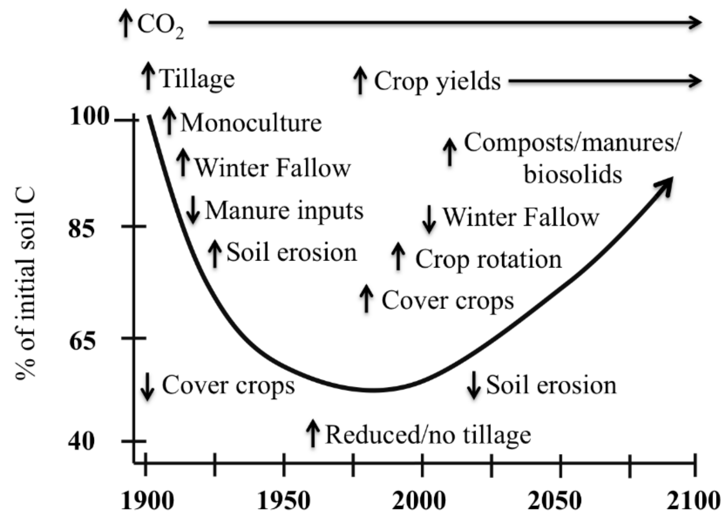

Figure 1. The effect of management practices, rising CO_2 and improved crop yields on the degradation of SOC and the effect of management practices to support SOC sequestration is shown since 1950 and projected to 2100.

Animal Manures Sequester SOC

The Rothamsted Experiment, started in 1849, showed the annual application of 35 Mg ha^{-1} of animal manure for 140 years steadily increased SOC (Jenkinson 1991). Numerous studies have shown the positive effects of animal manure on SOC sequestration. This is particularly evident in China, where decadal long-term experiments show the use of animal manure increases SOC and crop yields (Pan et al. 2009). Poudel et al. (2001a), showed the use of composted poultry manure annually significantly increased SOC in California.

On average, the availability of animal manure for crop production satisfies only 10% of crop N needs globally (Conant et al. 2013). Therefore, fertilizer N will continue to be used to support crop production. Human waste in the form of biosolids may also have the same positive effect on SOC sequestration than does animal manure. Silva et al. (2013), showed that the one time application of 100 Mg ha^{-1} of iron stabilized biosolids to open cast mine land in Brazil where topsoil was removed exposing the C horizon resulted in SOC sequestration 3 to 4 times higher than the original savannah. The use of biosolids has similar effects to animal manure in promoting SOC sequestration and should be considered as an important nutrient source to enhance soil productivity to sustain crop production in the future.

Conservation tillage impact on SOC sequestration

Conservation tillage incorporates a range of residue management and no till or reduced tillage practices. Many studies on conservation tillage systems show the majority of sequestered SOC occurs in the shallow zero to 15 cm soil depth. Studies comparing tillage treatments to depths greater than 30 cm often find no difference in SOC sequestration potential (Horwath et al.

2002). In an overview of conservation agriculture practices and associated ecosystem services, Palm et al. (2014) found that of more than 100 studies, about half reported SOC sequestration rates greater in tilled than no-tilled systems. Powlson et al. (2014), concluded that no-till systems have limited potential for climate change mitigation, primarily due to limited SOC sequestration potential. However, they also concluded that the accumulation of SOC at the soil surface in no-till systems improves soil properties, such as water infiltration and crop growth. The stratification of SOC in no-till systems is a positive ecosystem service that likely overshadows differences in soil C sequestration potential between tillage management.

Cover crops and crop rotation effects on SOC

In many ways, planting cover crops and diverse crop rotations have similar outcomes, most notably sequestering SOC (Poudel 2001). The use of cover crops provides soil surface cover during fallow periods, reducing erosion potential. Cover crops also provide valuable ecosystem services, such as increased water infiltration (Mailipalli et al. 2012), increase nutrient retention, reduced need for chemical N inputs, suppress weeds and increase soil microbial biomass (Drinkwater et al. 1998). For these reasons, cover crops are an essential soil management practice to promote soil health by increasing SOC and retaining and increasing the availability of N.

Potential to sequester SOC

Interest in using soils to sequester SOC through management with the goal of offsetting anthropogenic carbon emissions started in the 1990s (Barnwell et al. 1992). As a result, the potential for soil management to sequester SOC has been since extensively studied over the last three decades. The recent 4 per thousand (4PT) initiative, promoted by the United Nations General Assembly at the 21st Conference of Parties (COP21) held in Paris in 2015, is an integrated effort to promote SOC sequestration as a solution to offset fossil carbon emissions. The 4PT initiative contends that a small increase in soil C in agriculture, grasslands and forests would increase crop and fiber production while contributing to offsetting global carbon emissions.

Agriculture soil represents an important opportunity to sequester SOC. Agricultural soils are unique in the level of disturbance imparted upon them as a result of inputs and soil management practices. As a result, degraded agricultural soils have a larger potential sequester SOC. The average lower limit and upper limit for agricultural SOC sequestration is 0.14 and 0.38 Mg g C ha^{-1} y^{-1} (Minasny et al. 2017). Re-sequestering atmospheric CO_2 back to SOC could mitigate fossil C emissions to the atmosphere. The estimate of GHG emissions in the 4PT initiative is based on 8.9 Gt of fossil carbon emissions annually. Global SOC stocks to 2 m in depth are estimated to be 2,400 Gt (Batjes 1996). Therefore the ratio of 8.9 Gt soil C to 2,400 global SOC results in the value 0.4% or 4 per mil or thousand. This could limit global warming to an increase of 1.5° C as set forth in the COP21 by mitigating annual GHG emissions.

The average SOC content per hectare is estimated to be 161 t (Minasny et al. 2017). Assuming that the SOC sequestration rates of the 4PT initiative can be achieved, the average global rate would need to be 0.6 t C ha^{-1} y^{-1}. This value falls within the above the range of potential SOC sequestration mentioned above for agricultural land. The 4PT initiative value of

0.6 t C ha^{-1} y^{-1} is an average value, suggesting that actual SOC sequestration amounts would be higher or lower depending on soil type and region.

There are reasons to suspect that reported potential SOC sequestration values have been overestimated. Most reported values are done on research facilities where management practices are often done year in and year out consistently. For example, the same crop rotation or management practices are implemented for decades without consideration of economic constraints that often confront farmers. For example, a decadal project performed at the University of California Davis from 1988 two 2000 on the transition from conventional to low input/ organic agricultural practices determined that low input system (a hybrid between conventional and organic agriculture systems) increased SOC with annual winter cover crops and reduced chemical inputs (fertilizers and pesticides) (Poudel et al. 2001). The low input system had greater than 97% system N use efficiency and the highest crop yields, however was not economically viable compared to the conventional system with no cover crops and chemical inputs. Mitchell et al., (2107), in a long-term study found that the use of cover crops and no-till in the San Joaquin Valley achieved SOC sequestration comparable to the upper rate mentioned in the previous paragraph. These examples demonstrates that researchers can develop appropriate solutions towards climate friendly agricultural systems, but their practical application is constrained by not addressing the farmer's economic situation. However, Singer (2003), found in comparing 125 archive soil samples over a 60 year period in California that intensively managed and irrigated systems have increased in SOC on average from 1.06 to 1.34% likely reflecting increases in crop productivity and total residue inputs overtime. For these reasons, California farmers have the potential to sequester SOC using demonstrated soil management practices.

Nitrogen is required to sequester SOC

SOC sequestration cannot occur in the absence of N. The C to N ratio of stable SOC ranges from 8 to 12. The SOC sequestration rate promoted in the 4PT initiative would require an additional 100 Tg N y^{-1} assuming a soil C to N ratio of 12 (van Groenigen et al. 2017).

Fertilizer N inputs have increased overtime resulting in increased food production. The inefficient use of N in cereal crops suggest that residual N maybe available for SOC sequestration. However, less than 7% of applied fertilizer N is available to subsequent crops suggesting the N is likely lost from the system via leaching, runoff and gaseous routes (Ladha et al. 2005). After 40 years of synthetic fertilizer N applications that exceeded grain N removal by 60 to 190% at the longest continuous corn experiments at the Morrow Plots in Illinois, a net decline in SOC was observed (Khan et al. 2007). In addition, it was also found that soil N was depleted in the Morrow Plot despite the excess N inputs (Mulvaney et al. 2009).

Conclusion

The role of soils in mitigating climate change through SOC sequestration has been studied extensively for the last three decades. Many of the soil management practices discussed here have been shown to significantly increase SOC sequestration. Most of these results have been obtained from carefully planned studies at research institutions and less so on farmer fields. As suggested, this may overestimate SOC sequestration due to a omitting economic constraints that farmers are confronted with as well as not addressing the variability in management practices and soils resources that effect SOC. However, both research plots and farmer data show there is potential to sequester SOC in California to improve soil health.

Soils will play a major role in mitigating climate change, however the expectations to mitigate fossil C emissions set forth in the 4PT initiative maybe overly optimistic. Despite this optimism, the goal of SOC sequestration is of paramount importance and independent of the expectations of the 4PT. The benefits of promoting SOC sequestration range from maintaining or increasing crop productivity and supporting vital ecosystem services and should be supported through initiatives to promote soil health.

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Methods to Track Changes in Soil Biological Properties under Different Management Practices

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Introduction

Soil health testing is aimed at achieving multiple goals including: understanding soil constraints beyond nutrient limitations and excesses, targeting management practices to alleviate those constraints, measuring soil improvement or degradation from management, improve awareness of soil health, enable valuation of farmland, and enable assessment of farming system risk. Soil microbes play a direct role in driving multiple soil chemical and physical processes important for overall ecosystem function, but also have direct and indirect effects on plant productivity and quality. As a result, we suggest that soil conservation and regeneration should focus not only plant nutrient status and erosion control but also on the status of the soil biological community, its function, and overall soil health. The overall goal of this project was to identify the linkages between soil health management practices (individually and collectively) and soil health indicators on an array of soil samples collected from across the USA under different management practices.

Approach

619 samples soil samples (0-15 cm) were collected from across the USA from a variety of soil types, climate zones, and agronomic or rangeland practices (Figure 1). These include long-term, replicated agricultural research sites from OR, MN, IN, IL, and CA; and five USDA Plant Materials Center Cover Cropping Trials from MO, FL, MD, ND, and AK; and producer-owned/operated fields and long-term ranching operations. Samples were submitted for the following suite of soil health measurements: Cornell's Comprehensive Assessment of Soil Health (CASH), beta-glucosidase activity (BG), and phospholipid fatty acid (PLFA) profiling of the microbial community (Buyer and Sasser, 2012; Moebius-Clune et al., 2016; USDA-NRCS, 2014). Molecular analysis (16S) also was conducted on a subset of samples.

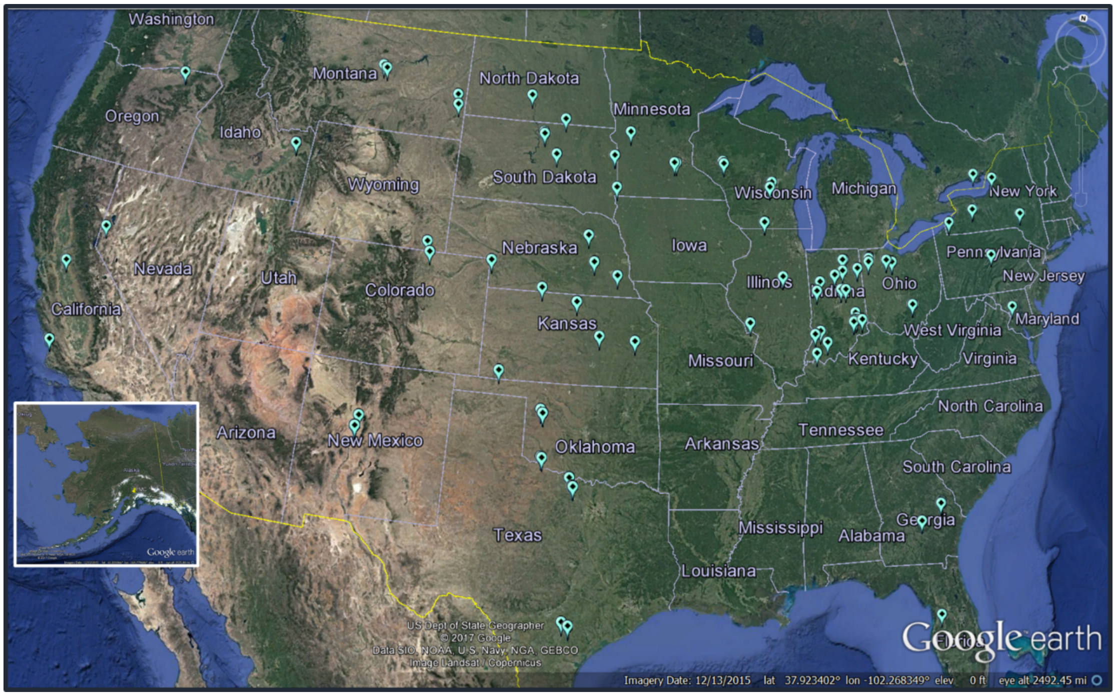

Figure 1. Map indicating location of soil sampling effort in agricultural and rangeland fields across the USA.

Results

Of the soil samples analyzed with PLFA and CASH (N=233), overall CASH score and total PLFA concentration were positively correlated ($p<0.0001$) supporting the concept that microbial abundance plays a pivotal role in soil health processes (Figure 2). Management practices are also related to various soil health indicators; for example, based on 146 samples, as cover crop richness increased, active carbon increased (Figure 3). Using examples from the Century Experiment at the Russell Ranch at University of California at Davis (http://asi.ucdavis.edu/programs/rr/about/century-experiment), cover cropping in a corn-tomato rotation had a positive impact on soil health indicators including active carbon (Figure 4), soil respiration (Figure 5), and abundance of arbuscular mycorrhizal fungi (Figure 6) based on PLFA analysis.

Additional samples and analyses are on-going. Ultimately, the indicators responsive to management and those that best predict ecosystem function and productivity will be identified. An overarching goal is to better quantify how management practices influence soil health.

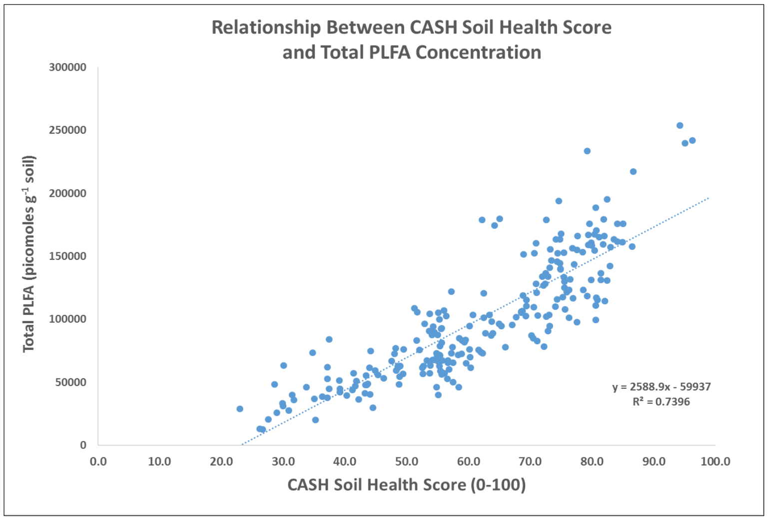

Figure 2. Relationship between CASH soil health score and total PLFA concentration

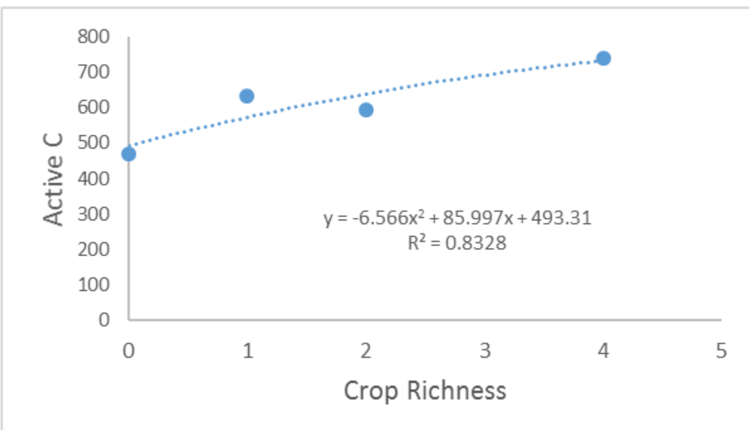

Figure 3. Relationship between cover crop richness and active carbon

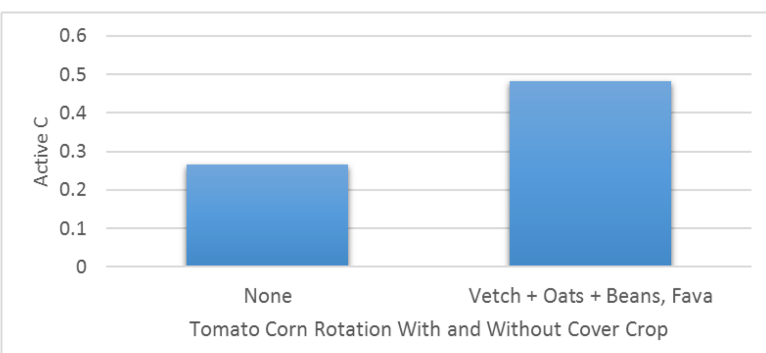

Figure 4. Effect of cover crop (vetch, oats, and fava beans) in a tomato-corn rotation on active carbon at the Century Experiment, Russell Ranch.

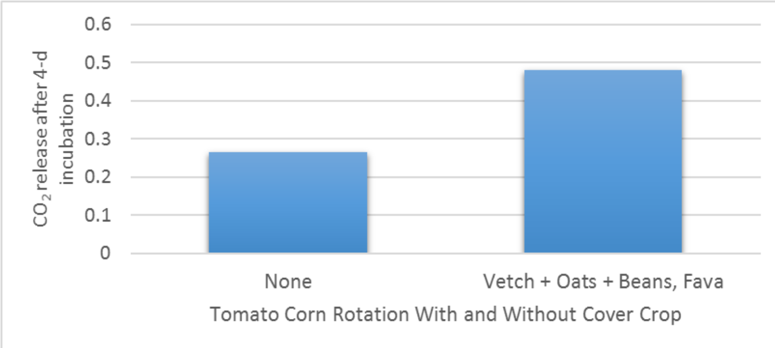

Figure 5. Effect of cover crop (vetch, oats, and fava beans) in a tomato-corn rotation on soil respiration (CO_2 release after 4-d incubation) at the Century Experiment, Russell Ranch.

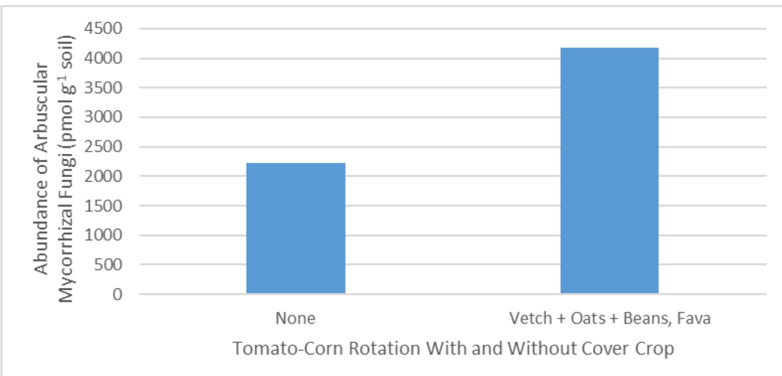

Figure 6. Effect of cover crop (vetch, oats, and fava beans) in a tomato-corn rotation on abundance of AMF at the Century Experiment, Russell Ranch.

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Dr. Hero Gollany (USDA-ARS, OR), Dr. Justin Derner (USDA-ARS, WY), Dr. Eileen Kladviko (Purdue University), Dr. Kristie Maczko (Univ WY), and Timm Gergeni (Univ WY).

Practical Considerations Toward Improving Soil Health and Functionality: Observations from One Organic Farm after 25 Years

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Assessing or measuring soil health has become a topic of renewed interest and emphasis. This presentation will cover practices employed and observations noted on a single large organic vegetable farm over a 25-year historical period. The premise is that crop performance in relation to yields, quality, and overcoming of typical plant diseases, insects, and nematodes is the true measure of soil health. Soil functionality with respect to crop performance, without constant interventional support from fungicides, nematicides, and fumigants, is the practical assessment or report card of soil health. In this presentation, examples will be given of the disappearance or avoidance of various common soil diseases and pests that has occurred over the 25-year period resulting from the implementation of organic farming practices.

Keywords: Organic farming practices, vegetable crops, soil health, soil disease and pest management

American Society of Agronomy
California Chapter

2018
Session #6

Sustainable Use of Water

Session Chairs:

Sharon Benes & Dan Munk

Overview: Sustainable Groundwater Management Act Implementation

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January 10, 2018

Keywords: SGMA, groundwater, sustainable water use, GSA, GSP, overdraft

Just over three years ago, the Sustainable Groundwater Management Act (SGMA) was signed into law. This new law provided a significant change in the way our water resources, not just groundwater, are to be managed. A very important finding of the Act was the recognition that groundwater management in California is best accomplished locally.

Consider three key components of SGMA. First, reaching sustainability within groundwater basins; the mitigation or avoidance of significant and unreasonable undesirable results (i.e., chronic lowering of groundwater levels, land subsidence, and degradation of water quality). Second, the resources are to now be managed with consideration to all beneficial users and beneficial uses of groundwater. Third, to achieve success, significant stakeholder outreach and engagement must be conducted, and perhaps in ways not done prior.

Sustainability was not specifically defined in the Act and it is the responsibility of the locals to determine. Something for the locals to consider can be found within the common definitions of sustainability - *the capacity to endure and be healthy over time and the reconciliation of environmental, social equity, and economic demands*.

Sustainable groundwater management will be implemented through the formation of Groundwater Sustainability Agencies (GSAs) and the development of Groundwater Sustainability Plans (GSPs). GSAs were required to form by July 1, 2017, and did so successfully by covering nearly 100 percent of the required high and medium priority groundwater basins. GSPs are required to be developed for each basin, and must result in the avoidance or mitigation of significant and unreasonable undesirable results within a 20-year time frame. For basins identified as being subject to critical conditions of overdraft, GSPs must be submitted to the Department of Water Resources (Department) for review and approval by January 31, 2020; the remaining high and medium priority basins have until January 31, 2022 to complete and submit their GSPs.

The Department is responsible for providing planning, technical, and financial assistance to facilitate the development and implementation of GSPs. For planning assistance, the Department implemented a Regional Coordination program and identified key staff for primary engagement and communication with the GSAs and stakeholders. Via a Facilitation Support Services program, the Department funds professional facilitators; the initial phase supported GSA formation and the current phase is supporting basin-scale coordination and outreach. In addition to the Regional Coordinators, the Department has also identified key points of contact for each basin – a dedicated DWR staff to be a liaison with the GSA(s) during development of the GSP and can provide assistance as needed to address the needs and concerns within the basin. The Department's technical assistance has included the development of Best Management Practices (BMP), Guidance Documents, and a technical report on Water Available for Replenishment.

The latest and forthcoming BMP is for the establishment of Sustainable Management Criteria (SMC). The SMC BMP explores the activities, practices, and procedures for defining sustainable management criteria as required for GSPs, and characterizes the relationship between sustainability goal, undesirable results, minimum thresholds, and measurable objectives. The Department's technical assistance also includes the development of statewide datasets and tools. These include interactive maps such as the Water Management Planning Tool, a Disadvantaged Communities Mapping Tool, and a Basin Boundary Assessment Tool. Additionally, the Department developed and released interactive maps to display and share land use data and well completion reports. Technical support is also available for a few existing hydrologic modeling codes and applications, as well as guidance to assist with incorporation of climate change into GSPs. Furthermore, the Department developed an online clearinghouse for SGMA information related to public notification, reporting, and comment. The SGMA Portal includes information on GSA formation and status, Adjudicated basin reporting, Alternative plan submittals, Basin Boundary Modifications, GSP initial notification, and will later also include GSP reporting functionally (www.water.ca.gov/groundwater/sgm).

The current phase of SGMA implementation will focus on local GSAs developing GSPs and the Department will be providing technical assistance, as requested, to aid the local effort. Technical support services will focus on building capacity within basins for basin-wide coordination. Technical services will likely include installation of groundwater monitoring wells and providing support for hydrologic modeling activity. In the near term, the Department will also be completing review of Alternative plans, releasing draft basin reassessment (priority) results, and conducting a second round of basin boundary modifications.

Proposition 1 provided $100M in grant funding for the Sustainable Groundwater Planning Grant Program. In March 2016, about $6.7M was awarded to counties with stressed basins to complete various projects related to GSA formation and/or addressing data needs for GSPs. A solicitation for the balance of the available grant funds (about $86.3M) closed December 2017. Proposed projects include those that directly benefit a Severely Disadvantaged Community and/or support development of GSPs. The Department expects to announce final funding awards in Spring 2018.

Although much has been accomplished the last three years by both the Department and the locals, the next few years will likely be challenging times for all as we progress toward full development and implementation of sustainable groundwater management. The Department looks forward to the success of local GSAs with development of GSPs and achieving sustainability.

American Society of Agronomy

California Chapter

2018

Session #7

Applied Crop Management

Session Chairs:

Stan Grant and
Michelle Leinfelder Miles

Understanding and Interpreting Soil and Plant Tissue Lab Reports

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Keywords: soil, plant tissue, laboratory analysis

Summary

Reports differ substantially from lab to lab. Test results can be given in a variety of units that can be confusing, and lab reports differ in the quality of information provided, including units, reference ranges, interpretation, methods used, quality control used, and method detection limits.

A lab report should have clear identification of the samples tested, clear identification of the tests performed, and understandable units. It can be helpful if the report includes an interpretation of the results, information on what testing procedure was used, and the method detection limits. The type and quality of the information provided in reports differs substantially between labs.

The labels of test methods can be confusing. Labs tend to label tests by client expectation or need. For example, a lab might erroneously label EC results as “soluble salts”, or nitrate-N as “nitrogen” to make the report simpler. There is no simple way of understanding these misnomers without knowing the methods used to test the samples.

Units can also be different between labs and are a big source of confusion. Fertility soil tests are typically reported as per mass of solid, such as meq/100 g, mg/kg (ppm), or percent; whereas, soil salinity tests are reported as per volume of liquid, such as meq/L or mg/L (ppm). To convert from a liquid to a solid basis, the saturation percentage can be used. Note that many labs do not offer saturation percentage as a routine test. Plant tests are typically on a per mass of solid basis, such as mg/kg (ppm) or percent; whereas, water and wastewater are as per volume of liquid, mg/L (ppm) or meq/L. Note that “ppm” is a poorly defined unit because it can mean mg/kg or mg/L.

It is an important function of the testing lab to demonstrate that test results are both accurate and precise on every set of samples tested. Accuracy is the closeness of the measured value to the “true value”. Precision is the agreement between replicate measurements. Unfortunately, precision and accuracy data are typically not provided. Duplicate analysis results are typically used to assess the precision of a method, and reference materials (samples of known concentration) are used to assess accuracy. It is a good idea to add you own duplicates and samples with known concentration to the samples you submit. Samples with known concentration can be purchased at http://www.naptprogram.org.

Many labs report an optimum range or interpret results as high, sufficient, or low. It is not always clear how the lab established these ranges. Many of these ranges originally come from University of California (UC) research using UC methods; however, not all labs follow UC methods, or they use modified UC methods. UC recommendations may not be appropriate. This is one reason it is important to have information on what method was used. Knowing the method used can also be important when you are referencing the method in a paper, verifying that an appropriate method was used, or when trying to compare test results from another lab. Unfortunately, many labs do not report the method used. This information may be located on their website or be available by request.

Method detection limit (MDL), also called limit of quantitation (LOQ), is the lowest concentration that can be measured accurately and with precision. Significant figures are an additional way of assessing the lowest accurate result possible. Knowledge of the MDL is important because method error increases dramatically as the results approach the MDL. Numbers smaller than the method detection limit or smaller than the last significant figure are essentially random. Since many labs do not report MDL, it is common to mistakenly put value in results near the MDL that actually have very high error.

It is important to carefully check the results in a report. Verify that results are reasonable based on sample location and history. Verify that results are reasonable based on chemistry. For example, carbonate should not be present at low pH, and the sum of exchangeable cations in soil should be close to the cation exchange capacity (CEC). The sum of the cations in a water sample should be close to the sum of the anions. Total nitrogen should be more than the sum of nitrate-N and ammonium-N. Total carbon should be greater than organic carbon. Verify that results are reasonable based on possible lab errors. Check the quality control data if it is provided. Look for common lab errors such as switched samples, double weighed samples, identical sample results, and dilution errors (all values seem off by a constant factor).

Agricultural labs are not accredited or certified. Especially for research samples, it is a good idea to use a lab that participates in a proficiency program (NAPT or ALP). Check lab results by submitting duplicate samples and samples with known values. These can be purchased from the NAPT or ALP proficiency programs.

Applied Advancements for Improving Yield and Quality of Treefruit and Nut Crops.

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Keywords: potassium, bee removal, bloom sprays

Introduction

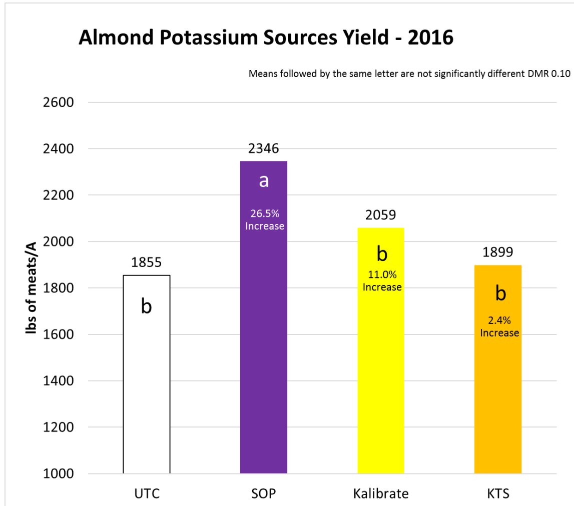
Three topics will be discussed during this Applied Crop Management Tools session. They will include “Managing Soil Applied Potassium on Low CEC Sandy Soils”, “The Impact of Early Bee Removal on Pollination and Yield of Almond”, and “The Impacts of Sprays Applied During Bloom”.

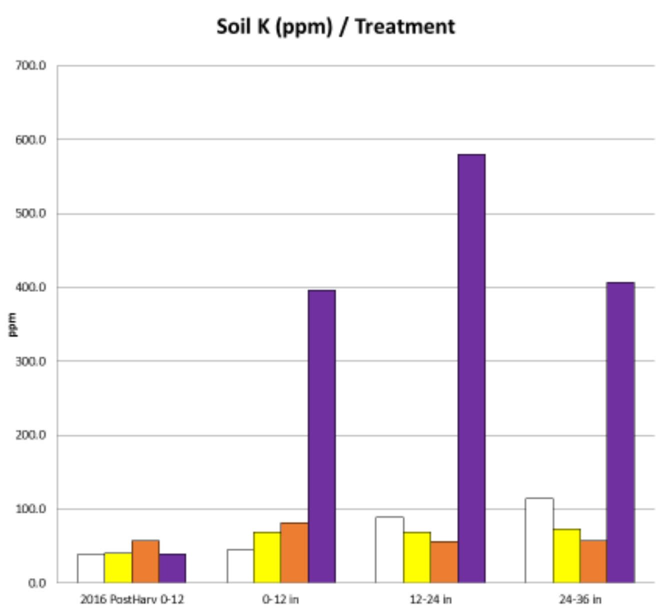
Managing Soil Applied Potassium on Low CEC Soils

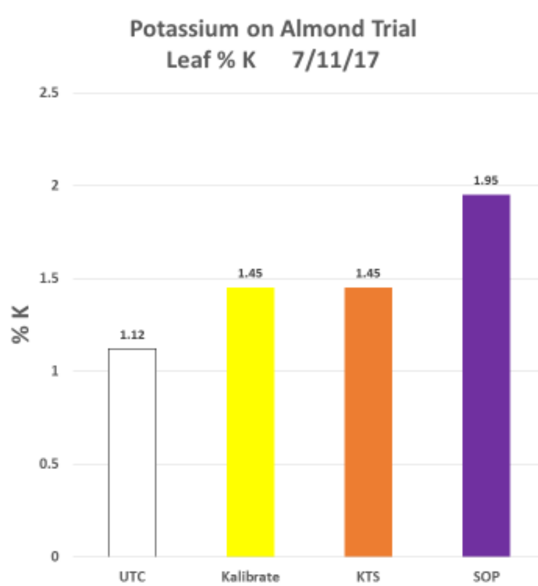
Soil applied potassium sulfate has historically been applied to orchard crops in concentrated bands, parallel to the tree rows and approximately 3 to 4 feet away from the trunks. Quantities would typically be in the 1000 to 1500 pound per acre rate. The rationale for this methodology was that potassium needed to be applied in large dose concentrated bands to prevent soil fixation and immobilization of the K+ ions. While there is some truth to this statement, certain factors depending on the locale and the soil texture can alter these results. In high CEC soils with significant clay content and/or high organic matter, K+ can become fixed and sparingly available to the roots.

Many orchards in California are grown in very sandy soils with low CEC’s in the 2 to 3 milliequivalent range. Under these conditions, potassium can move down very readily with the water phase. An added factor when microsprinklers or drip irrigation is used is a very shallow and dense root mass that can be less than an inch below the soil surface. The combination of very mobile K+ and this accessible root network allows for lower rate per acre applications and even broadcasting the material if directed into the weed strip area. Many growers have been able to sustain K levels in the trees with low doses of dry potash or fertigated applications of liquid formulations such as KTS or potassium carbonate under these conditions.

Independent research trials (Wes Asai Pomology Consulting) in the northern San Joaquin Valley have demonstrated that annual broadcast applications of potassium sulfate at 400 lbs./A can sustain almond yields and spread a growers’ cost over several years versus the major single year expense incurred during large dose applications. The data also indicated that in these low CEC soils, potential leaching losses similar to nitrogen was possible at those larger doses.







The Impact of Early Bee Removal on Pollination and Yield of Almond

During the period of late-January through early-March, honeybee colonies are placed in almond orchards for pollination. This is generally a safe environment for the bees, however in some cases due to the use of sprays in the orchards or on surrounding crops, hives are removed from the orchards before the almond bloom is completed. The general belief is that the last 10% of the blossoms represents an insignificant amount of yield (Almond Board of California Best Management Practices), thus hive removal for bee safety will not impact the crop. Many growers will debate this and request that bees be left in the orchards until bloom is completed, justifying their $175 to $200/hive cost to rent the bees.

Pesticides can kill bees in pollinating crops (Hooven et al., 2006), (Chesick et al., 2015), (Johansen & Mayer, 1990) or negatively affect the brood (Fine et al., 2017). Due to these concerns, beekeepers are anxious to move hives from orchards as soon as possible, even if the almond grower is not the one doing the spraying.

To evaluate the potential effect on crop set with early hive removal, two separate studies (Wes Asai Pomology Consulting, 2010, 2017) were conducted to measure the contribution to crop load of the last 10% of the blossoms to open on the last varieities to bloom. The studies were done on the Butte and Padre varieties in 2010 and on the Padre in 2017. In the 2010 study, limbs on 15 Butte and 15 Padre trees where unopened blossoms represented the last 10% of the bloom were counted. In 2017, 23 Padre trees had limbs with unopened blossoms counted that represented the last 10% of the bloom. Percent set counts were made in May. In 2010, the Butte set 56.4% of the flowers and the Padre 64.1%. Based on average kernel weights, this would extrapolate to approximately 411 lbs./A. In the 2017 study, the Padre set 23.7% of the flowers. This would extrapolate to 163 lbs./A. One can use their own prices per pound to project potential revenue.

The Impacts on Pollination of Sprays Applied During Bloom

There are many factors that can affect the decision whether to apply sprays during the bloom period. These may include a concern for the bees, management of diseases, nutritional requirements and effects on pollination. The previous topic discussed the potential negative effects of insecticides on bees. Of additional concern are other sprays that may include products such as fungicides, adjuvants or combinations of both. There is evidence that these materials can have negative effects on bees (Pilling and Jepson, 1993) (Fine et al., 2017). Also, the Almond Board of California Best Management Practices brochure suggests not applying fungicide sprays during bee activity. This creates a dilemma since inclement weather during bloom may necessitate the need for fungicides, and a review of the University of California Pest Management Guidelines (Adaskaveg, 2017) suggests the optimum timing for the majority of bloom diseases is during the full-bloom period.

An added factor is the inclusion of foliar nutrients during these sprays. Certain materials are potentially phytotoxic to the stigma of the flower (USDA AG Handbook 496), where others pose a threat to the entire flowers, developing crop and foliage. Some materials such as zinc or boron can be directly toxic in sufficient concentrations. Others, such as non-buffered phosphites can have pH levels below 2 and cause direct injury or indirect injury by increasing the solubility of free metal ions.

There are synergistic phytotoxicities such as oils near captan, sulfur or chlorothalonil applications.

There are also specific varietal incompatibilities. Sulfur on apricots, azoxystrobin on apples or malathion on certain varieties of cherries.

Then there is the tank mix which simply has "too much stuff" with unknown compatibilities. Spray tanks that may contain an insecticide, fungicide, buffer, adjuvant, nutrients, phosphites, humic acid and seaweed extracts all combined are more common than one might think. To know all potential incompatibilities of all products is an insurmountable task.

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Salinity Management – Soil and Cropping Systems Strategies

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Key words: salinity, leaching, soil, irrigation

Introduction

Salt problems occur on approximately one-third of all irrigated land in the world. Some soils are salty because parent materials weather to form salts; while on croplands, salts may be carried in irrigation water, added as fertilizers or other soil amendments, or be present due to a shallow saline groundwater. The salt load of a soil is typically estimated by measuring electrical conductivity (EC). Positively-charged cations (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) join with negatively-charged anions (Cl^{-}, SO_4^{-}, HCO_3^{-}) to form soluble salts ($NaCl$, $CaCl_2$, $MgCl_2$, $CaSO_4$, $CaCO_3$, and KCl). In a solution, the ions disassociate and will move toward an electrode of the opposite charge, creating a current that can be measured with an EC meter. When the solution comes from a soil saturated paste, the abbreviation used is ECe, and when the solution is water, the abbreviation is ECw. A saline soil is one having an ECe greater than 4 dS/m. In addition to EC, a salt-affected soil may be characterized by sodium adsorption ratio (SAR) or exchangeable sodium percentage (ESP). Both SAR and ESP characterize the sodium status of an alkaline soil (a soil with pH greater than 8.5). A sodic soil is one having a SAR of at least 13.

Effects of Salinity on Plant Growth

Salt directly impairs plant growth by exerting osmotic stress that results in decreased turgor pressure in plant cells, by causing specific ion toxicities that vary by plant species, or by degrading soil conditions that limit plant water availability. Osmotic stress is the most common means by which salt impairs plant growth (Hanson et al., 2006). Under a low salinity condition, the concentration of solutes is higher in plant roots than in the soil-water solution. This means that water moves freely into the plant roots because there is more force, called osmotic potential, pulling the water into the plant roots than there is force holding the water to the soil particles. Under conditions of higher soil salinity, plants must transport solutes within the plant to the roots in order to keep root solutes higher than soil-water solution solutes to avoid water stress. Remobilizing solutes requires energy, and that energy, then, is not used for plant growth. Thus, some plants will not show specific salt-induced symptoms as a result of saline soil conditions; rather, they may just exhibit lower growth or generic stunting which may or may not be realized by the farmer as being salt-induced (Hanson et al., 2006).

Plant growth may also be impaired by specific ions, like sodium (Na^{+}), chloride (Cl^{-}), or boron (B), which can accumulate in plant stems and leaves. When toxic concentrations of Cl^{-} or B occur in plant leaves, it appears as yellowing and progresses to burning along the leaf edges. The presence of Na^{+}, in addition to specific toxicity, may limit plant calcium, magnesium, or potassium uptake, and therefore, result in plant nutrient deficiencies. When leaves yellow or burn, it reduces their photosynthetic capacity, thus reducing plant growth.

In addition to the direct effects of salinity on plants, plants may also be affected by salinity if soil conditions are degraded and water infiltration and drainage are impaired. Degraded soil conditions may exhibit white or black crusts or wet spots on the soil surface. The white crusting is the result of evapoconcentration of salts on the soil surface, and the black crusts form because humus is carried upward with water as water evaporates. Slick spots form because the soil particles are completely dispersed and soil structure is lost. The soil swells, and water infiltration will decrease. Poor infiltration can result in standing water on the soil surface or poor aeration in the soil pores, neither of which promotes plant health and growth.

Strategies for Salinity Management

In considering strategies for managing salinity, one should recognize the difference between applied water salinity and soil salinity. Crop salinity tolerances are expressed as both seasonal average applied water salinity and average root zone soil salinity. Irrigation water carries salts, and when irrigation water is applied to fields, salts are added to the soil. Salts accumulate in the soil at higher concentrations than they existed in the applied water. Also, salts may accumulate unevenly in the soil. For all of these reasons, it is important to test water and soil salinity regularly to understand baseline conditions and changes over time. With this knowledge, strategies like site selection, variety selection, soil amendments, and leaching may be employed to assist in salinity management.

Site Selection

Site selection is arguably the most important time to consider salinity management. Before a crop is planted, the irrigation water and soil should be tested for salinity. Preferably, the irrigation water should be tested over a span of time that would represent the irrigation season because crop tolerance values are expressed as the seasonal average applied water salinity. Soil may be tested for nutrient status on an annual basis, and EC may be a part of the nutrient status testing package. Consider, however, how deep the soil has been sampled for those tests. If soil salinity is a concern, soil should be tested in 6- to 12-inch increment depths to at least two feet. Increment depth samples should be kept separate for analysis. Several soil cores should be sampled over similar soil type. Over time, growers may not be aware of the salinity of their soil profile if soil has not been sampled and tested to sufficient depth. Management practices, like deep ripping before planting a permanent crop, or conditions of fluctuating shallow ground water, may redistribute salts that accumulated below the root zone of annual crops to a shallower level in the soil profile that could impact a subsequent crop. Limited water supplies due to drought and precision irrigation methods can exacerbate soil salinity. Growers should consider whether there are seasonal patterns of salinity or patterns across the field. These may indicate a need for managed off-season leaching or modifications to irrigation. In gravity-fed systems, modifications to irrigation may include increasing the on-flow rate of irrigation water, narrowing border checks, or shortening row length. If more than one irrigation source is available, consider using the best source, or mixing poorer quality water with better quality water, on seedling crops. Alfalfa seedlings, for example, have shown delayed emergence under saline conditions (Cornacchione and Suarez, 2015). Therefore, it is important to strive for low salinity soil conditions at the time of planting and use the best quality water available on seedlings.

Variety Selection

Relative salt tolerance ratings (i.e. sensitive, moderately sensitive, moderately tolerant, and tolerant) have been developed for various crops grown in California (Hanson et al., 2006).

Tolerance thresholds at which yields are expected to decline have been developed for various crops (Ayers and Westcot, 1985) and serve as guidelines for crop selection, but absolute tolerance will vary depending on climate, soil conditions, cultural practices (Ayers and Westcot, 1985), crop stage of development (Smith, 1994), and variety characteristics (Cornacchione and Suarez, 2015). Some alfalfa varieties may tolerate higher salinity based on the plant's ability to exclude Na^+ concentrations in the shoots and limit Cl^- uptake (Cornacchione and Suarez, 2015). Nevertheless, recognizing that growers need to select crop varieties for various characteristics, including yield potential, disease and insect resistance, and other objectives in mind, plant breeding should not be considered a substitute for soil salinity management.

Soil Amendments

Soil amendments are most effective in alleviating salinity conditions in saline-sodic and sodic soils because in these soils Na^+ is the dominant cation. Calcium amendments can replace Na^+ on the soil and improve soil structure so that Na^+ can be leached. Gypsum ($CaSO_4$) is the most common amendment and may be used in acidic or alkaline soils; it will not change the soil pH. Lime may also be added and would raise the pH of an acidic soil. If soil contains "free lime", (calcium carbonate, $CaCO_3$), then adding an acid, like sulfuric acid (H_2SO_4), will liberate the Ca^{2+} in the soil to form gypsum. Free lime may be present in alkaline soils. The following are considerations with adding soil amendments: 1) If soil infiltration is already good, then applying a calcium amendment might not be economical; 2) The amount of amendment depends on the amount of exchangeable Na^+ in the soil and could be costly; 3) The process can be slow because amendments must solubilize and react in the soil; and 4) Soil amendments do not eliminate the need for leaching.

Leaching

The primary management strategy for combating salinity is leaching, and leaching must be practiced when soil salinity has the potential to impact crop yield. Leaching occurs when water is applied in excess of soil moisture depletion due to evapotranspiration (ET). The leaching fraction (Lf) is the fraction of the total applied water that passes below the root zone. The leaching requirement (Lr) is the minimum amount of the total applied water that must pass through the root zone to prevent a reduction in crop yield from excess salts. In other words, the leaching requirement takes into consideration the crop salinity thresholds beyond which yield declines are expected. Leaching may occur during the rainy season or whenever an irrigation event occurs; however, leaching during the season may not be advisable because nutrients (like nitrogen) may be lost from the system.

Examples from Cropping Systems in the Sacramento-San Joaquin Delta

The Sacramento-San Joaquin River Delta region – for its soil type, climate, and water sources – is a unique agricultural region of California. Diverse crops grow in the Delta region, and alfalfa, processing tomatoes, and vineyards have accounted for approximately 30 percent of the agricultural acreage in recent years (Medellin-Azuara et al., 2016). Surface water from Delta channels is used for irrigation, and water quality (i.e. salinity) can vary over the year based on river flows, and daily based on sea water intrusion from ocean tides. Research project results illustrate the challenges associated with leaching salts under various cropping systems and irrigation methods in the Delta but suggest strategies for alleviating salty conditions under these conditions.

In a multi-year study (2013-2015) of drip-irrigated processing tomatoes (Aegerter and Leinfelder-Miles, 2016), leaching was observed to occur laterally away from the buried drip emitters (Fig. 1). This is similar to the results observed by Hanson and May (2011) in drip-irrigated cropping systems in the San Joaquin Valley. Salts concentrated in the top 10 cm (4 in) of soil and at about 90 cm (3 ft) below the surface, where fine-textured organic matter likely impeded downward water movement. Average root zone salinity worsened from 0.8 dS/m in Spring 2013 to 1.3 dS/m in Fall 2015. Even at 1.3 dS/m, the average root zone salinity was below the threshold at which yield declines are expected for processing tomato (2.5 dS/m; Ayers and Westcot, 1985). Nevertheless, rainfall was not sufficient in these drought years to leach salts during the winter seasons. Salts that are not leached may be redistributed in the profile and impact future cropping.

Electrical Conductivity, ECe (dS/m)

Depth (cm)	Spring 2013 Bed Center ↓			Furrow ↓	Fall 2015 Bed Center ↓							Furrow ↓
0 - 10	0.84	0.74	1.24		2.50	2.51	2.97	2.34	2.67	2.27	2.76	2.69
10 - 20	0.93	0.84	0.75	0.72	1.37	1.17	1.12	1.02	1.05	0.96	2.51	4.49
20 - 30	0.81	0.84	0.92	0.74	0.85	0.85	0.85	0.86	0.90	1.08	0.81	1.04
30 - 40	0.94	0.84	0.73	0.76	0.87	0.94	0.99	0.92	0.95	0.87	0.74	0.76
40 - 50	0.67	0.92	0.74	0.79	1.12	0.89	1.26	1.15	0.99	0.86	0.85	0.71
50 - 60	0.64	0.76	0.74	0.79	1.06	1.05	1.37	1.08	0.89	0.84	0.61	0.71
60 - 70	0.68	0.79	0.75	0.71	0.94	0.96	1.52	1.16	1.09	0.88	0.71	0.87
70 - 80	0.82	0.77	0.79	0.71	0.83	0.94	1.32	1.49	1.21	1.11	1.01	0.87
80 - 90	0.83	0.77	0.74	0.73	1.15	1.17	1.46	1.51	1.58	1.56	1.43	1.21
90 - 100	0.81	0.80	0.78	0.66	1.47	1.75	1.66	1.68	1.67	1.68	1.68	1.51

Legend*	2.5	3.5	5.0	7.6	13.0

Figure 1. Soil salinity (ECe, dS/m) of drip-irrigated tomato beds in Spring 2013 and Fall 2015. The year 2013 was the first year of drip irrigation in this field. Salts accumulated in the root zone over these three years of drought, and average root zone salinity worsened from 0.8 dS/m to 1.3 dS/m. Localized leaching occurred near the drip tape and laterally from the drip tape toward the furrow. Legend from Ayers and Westcot (1985) indicates the salinity at which 100, 90, 75, 50, and 0 percent yield potential is expected for tomatoes.

Over the same three-year period, the soil salinity profile and leaching fraction was evaluated in seven border check flood irrigated alfalfa fields. These sites varied in soil type, water quality, and groundwater depth, and results illustrate how inherent site properties influenced soil salinity profiles. Across these seven sites and three years, average root zone salinity ranged from 0.71 dS/m to 7.18 dS/m. At only two sites was an average root zone salinity below 2.0 dS/m maintained across the study period, the level at which 100 percent yield potential is expected for alfalfa. Some of the study sites likely accumulated salts because shallow groundwater impeded salts from leaching out of the root zone or low permeability soil impaired leaching. At a site with a higher permeability soil (fine sandy loam), soil salinity profiles indicate that perhaps irrigation could have been managed differently to achieve better leaching and lower soil salinity. At this site (Fig. 2), leaching was better on the top end of the border check than on the middle and bottom sections of the field. If irrigation water had a longer opportunity time for infiltration on the lower end of the field, this might have reduced salinity in the soil profile. This practice would have to be carefully monitored, however, to ensure that water does not sit on the field and result in root rot diseases. A different site, also with a fine sandy loam, showed that a high leaching fraction could be achieved, and even with high salinity irrigation water, a high leaching fraction maintained average root zone soil salinity below the crop tolerance level for alfalfa.

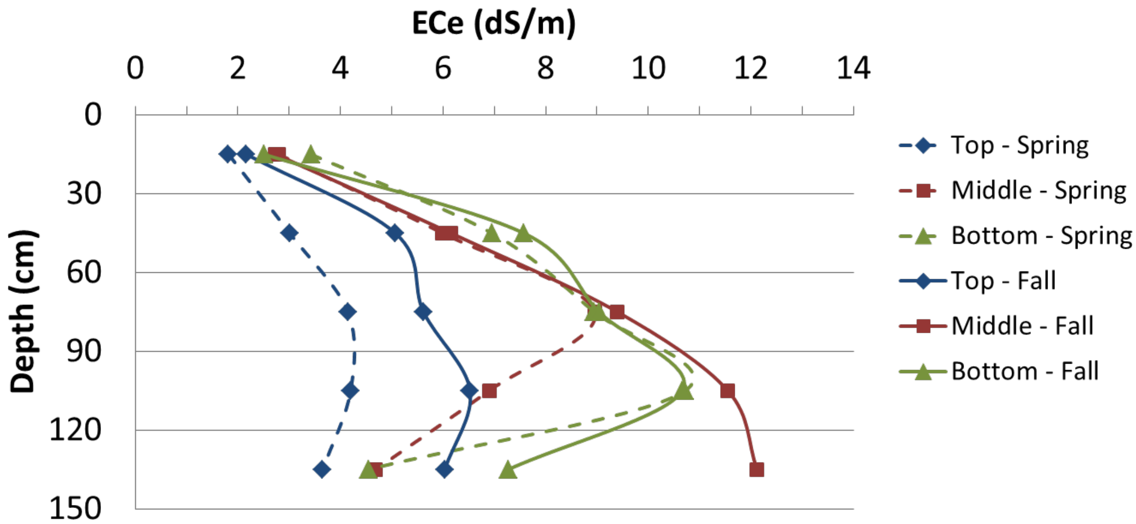

Figure 2. Soil salinity profile of a border check flood irrigated alfalfa field from the soil surface to a depth of 150 cm (approx. 5 ft) in the Spring and Fall 2014. Salinity was higher in the middle and bottom sections of the field compared to the top section of the field, indicating that the longer opportunity time on the top end of the field provided better leaching.

Finally, in a drip-irrigated vineyard, the soil salinity profile was characterized in a one-time soil sampling in August 2016. Similar to the aforementioned drip-irrigated tomatoes, the wetting pattern appeared to push salts away from the drip tape to approximately 120 cm from the vine row and 120 cm deep. This region of the soil profile had some of the highest salinity (Fig. 3). The saturation percentage (SP) at this depth was approximately 90 percent. The SP of a soil correlates well with soil texture, and when the SP ranges from 65-135 percent, the soil is characterized as clay (Neya et al., 1978). Clays, as fine textured soils, have low permeability; thus, the salts appeared to be accumulating at the depth where infiltration was inhibited by inherent soil characteristics. The average root zone salinity was approximately 3.3 dS/m. The soil salinity threshold for grapes is 1.5 dS/m, beyond which yield declines are expected. Thus, there was the potential for salinity to impact yield at this vineyard.

Grapes, South - Electrical Conductivity (ECe, dS/m)

Depth	Vine Row 0 cm	30 cm	60 cm	90 cm	Alley Center 120 cm
0 - 30		1.20	2.19	3.57	2.18
30 - 60		1.06	2.15	3.57	2.61
60 - 90		3.03	2.94	4.44	5.18
90 - 120		3.82	4.15	4.90	5.35
120 - 150		2.30	1.88	2.79	2.49

Legend*				
1.50	2.50	4.10	6.70	12.00

Grapes, South - Saturation Percentage

Depth (cm)	Vine Row 0	30 cm	60 cm	90 cm	Alley Center 120 cm
0 - 30		0.66	0.69	0.66	0.67
30 - 60		0.84	0.82	0.83	0.79
60 - 90		0.91	0.98	0.96	0.94
90 - 120		0.89	1.00	0.95	0.90
120 - 150		1.02	1.08	0.98	1.00

Figure 3. Soil salinity profile (ECe, dS/m) and saturation percentage (SP) profile of drip-irrigated vineyard soil. Salts appeared to accumulate approximately 120 cm (4 ft) below the soil surface where the SP indicated fine-textured/low permeability soil. Average root zone salinity was 3.3 dS/m. Legend from Ayers and Westcot (1985) indicates the salinity at which 100, 90, 75, 50, and 0 percent yield potential is expected for grapes.

In all three of these research projects, results indicate that more leaching is needed to avoid impacts to crop production because other management strategies would have limited impact or relevance. Soil amendments would likely not be helpful in these Delta soils that are usually acidic, and with the possible exception of alfalfa, salt tolerant varieties are not available or desirable. It is not always possible (or desirable) to apply enough water to leach salts during the growing season. In the Delta, low soil permeability soils or proximity of groundwater are inherent site characteristics that may inhibit leaching. Agronomic considerations, like disease prevention or fruit quality management, are considerations across agricultural systems and regions. Low winter rainfall may mean that leaching during the off-season is inadequate. All of these conditions put constraints on growers' ability to manage salts; however, growers may be able to enhance leaching during the off-season by leveraging rainfall with irrigation water to wet the soil profile before a rain event. For the Delta, maintaining water quality salinity objectives will also be important for maintaining soil quality and crop yields.

Summary

Salinity affects agriculture in arid climates throughout the world, impacting crop productivity and degrading soil resources. It is important to monitor irrigation water and soil salinity in cropping systems to understand baseline conditions and changes over time. Strategies for managing salinity include site selection, variety selection, soil amendments, and leaching. Growers should consider the salinity condition before a crop is planted by testing the soil and water, leaching salts, and managing irrigation for the most vulnerable crop stage (seedling/young trees or vines). Variety selection and soil amendments may help mitigate a salinity condition, but these do not eliminate the need for leaching. Leaching is the primary means of managing salinity and must be practiced when there is the potential for salinity to impact crop yield. The Sacramento-San Joaquin River Delta is an agricultural region that is impacted by salinity due to its soil types, climate, and irrigation and groundwater sources. Research results from the Delta illustrate the challenges associated with leaching in these cropping systems but suggest strategies for alleviating salty conditions.

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California Chapter

2018

Session #8

Managing Farm Energy

Session Chairs:

Dan Munk

IRRIGATION PUMP EFFICIENCY – THE EVOLVING ESSENTIALS

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PUMP EFFICIENCY and ENERGY COST – THE PROBLEM

About one-third of the irrigation pumps in California operate at less than 50% efficiency. Increasing overall pump efficiency from 50 to 60 percent for a typical well can reduce energy costs by 17% ($13,000 annually).

Energy expenses constitute up to 65% of the controllable operating costs on farms, yet many growers and managers don't have a good understanding of how pump efficiency is measured and how to use that data to manage ground water costs, maintenance and energy expenses.. Timely measurement of pump efficiency enables growers and pump managers to budget water costs and maintain pumps for effective, economic performance of their irrigation systems.

OVERALL PUMP EFFICIENCY BASICS

Overall Pump Efficiency is the relationship between power consumed and the rate of water delivery at a given pumping head. The more efficient the pump and motor, the lower the energy use. The formula for calculating OPE is

(Flow X Total Dynamic Head) divided by (HP-in X 3,960)
Flow - GPM or rate in gallons per minute
Total Dynamic Head - TDH or total lift of the pump including the feet of lift from the Pumping Water Level plus the discharge pressure X 2.31
HP-in – Horsepower-In - the electric demand stated in kilowatts (kW)
  Note: kW times 1.34 = input HP; or, nameplate HP times .764 = kW
3,960 – Constant (output HP factor of motor)

Using the equation above, OPE on a sample well with:
Flow – 750 gallons per minute
Total Dynamic Head - 397 feet of total lift in feet
  Pumping Water Level measured 300 feet
  Discharge Pressure at pump – 42 psi (measured psi time 2.31 times equals 97 feet)
HP-in – 134 kW (measured)

The results:

750 (GPM) X 397 (TDH)	=	297,750	
3,960 (Constant) X 134 (HP-in)	=	530,640	the "Wire to Water" OPE is 56%

OPE is a factor of the efficiency of the motor, the downhole bowls, impellers and shaft, friction and electric losses plus conditions in the well such as variable pumping water levels. Irrigation wells often degrade over time as the screen is eroded by use or becomes restricted by biological matter, as the gravel pack becomes less permeable, and as the water levels vary.

ADVANCED PUMP EFFICIENCY PROGRAM

Based on APEP tests of about 40,000 pumps in the last 15 years, the average OPE in PG&E territory is about 53%. After repair or replacement, the average pump OPE is increased to 63%. Pumps with motors in the range of 100 to 150 HP-in should be above 60% efficient. Below 50% OPE is considered poor. Very few tested pumps are above 70% OPE.

The Center for Irrigation Technology at California State University, Fresno manages the Advanced Pump Efficiency Program "APEP," a long-term rate payer funded program administered by PG&E using funds from the public purpose charge. In southern California, SoCal Edison provides similar subsidized programs. Public purpose funds are used to subsidize pump efficiency testing as well as to provide incentives for pump repairs and replacement.

BEST PRACTICES and CONTINUOUS PUMP TEST REPORTING

Best practices mandate conducting a pump test twice during each pumping season. The typical hydraulic test report includes the measured variables as well as standing water level, draw down and the Specific Capacity.

Specific Capacity of a well has a strong correlation to the health of the reservoir and the condition of the downhole assembly over time. Growers use Specific Capacity to evaluate the need for remediation and to measure the effectiveness of periodic downhole treatments such as chemical and brush jobs, casing conditions, bowl repairs and other problems including silting of the gravel pack.

Pump efficiency tests have traditionally been conducted by independent firms using on-site personnel and portable measurement tools.

Pump Efficiency and Specific Capacity tests are now conducted on a continuous basis using meters and sensor in the well without the need for on-site personnel or tools. Real time, continuous analysis can predict problems and easily compare results from past tests (in paper formats as well as newer continuous tests.)

Continuous testing accurately compares test results to the manufacturer's pump curves and gives indications of excessive wear, casing problems and screen conditions to assist in the decision to retrofit or repair equipment using objective economic analysis.

Continuous pump tests, in coordination with occasional physical tests can be economically employed on electric motors with soft start, VFD or traditional electric panels as well as diesel and natural gas fired engines. Expertly designed pump test programs include other information such as motor amperage harmonics, water Ph and conductivity, analysis of motor assembly vibration and evaluation of shaft lubrication.

ADDITIONAL BENEFITS OF PUMP EFFICIENCY TESTING

In addition to energy, water and maintenance performance, online continuous pump reports enable growers and operators to evaluate and participate in Demand Response, load shifting, tariff analysis, renewables including solar and battery storage as well as groundwater sustainability programs and reporting.

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Opportunities for Energy Demand Management in Irrigated Agriculture

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Keywords: irrigation, energy, demand management

Introduction

The California Energy Commission (CEC) is supporting development of a decision support system for irrigation management to facilitate on-farm participation in energy demand management incentive programs. Balancing on-farm irrigation and energy needs with the dynamic energy markets is becoming increasingly important to energy users, energy producers and California's energy infrastructure.

This paper will outline linkages between operational imperatives of the energy grid and irrigation energy demands. Economic opportunities for on-farm energy conservation and energy load shifting will be discussed. Potential economic benefits and challenges of demand management programs will be illustrated, including: (i) timing of pumping energy use to take advantage of favorable utility rates at off-peak hours; (ii) responding to interruptions in energy supplies for a farm with limited system capacity. We will present an overview of an irrigation planning and management tool designed to facilitate participation in demand management programs.

Energy supply issues and opportunities in irrigated ag in the San Joaquin Valley

California's electricity system is undergoing unprecedented change. California's current goals call for meeting 50% of California's retail electricity sales with renewable energy by 2030 and reducing greenhouse gas (GHG) emissions to 40% below 1990 levels by 2030 (CARB, 2016). A 50% renewable electricity system in California will have a high penetration of variable solar and wind generation. Fluctuations and uncertainty of variable generation will make the operation of an already complex electricity system even more complicated. One way to offset the unpredictability of renewable resources is through demand response programs (DR), by which end users are induced to change their electric usage to match demand to supply. Historically, DR resources have been used to reduce the system level peaks (e.g. hot summer days). As California moves closer to its target of 50% renewables, traditional DR can provide local reliability, but more importantly faster time scale DR services (also referred to as Ancillary Services) will be more important for facilitating the intermittency of renewable generation.

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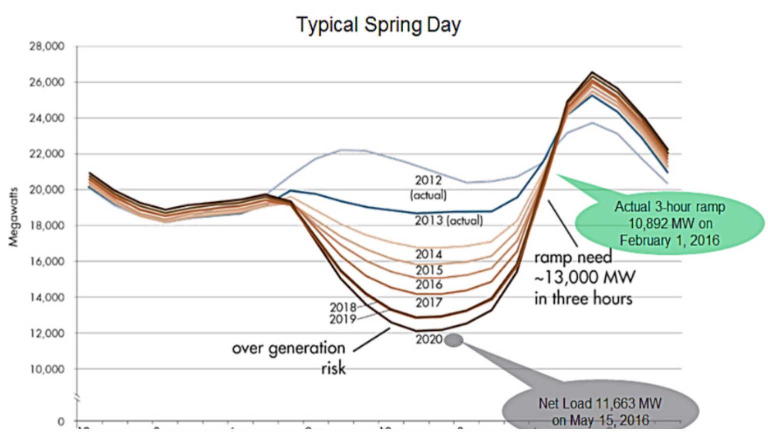
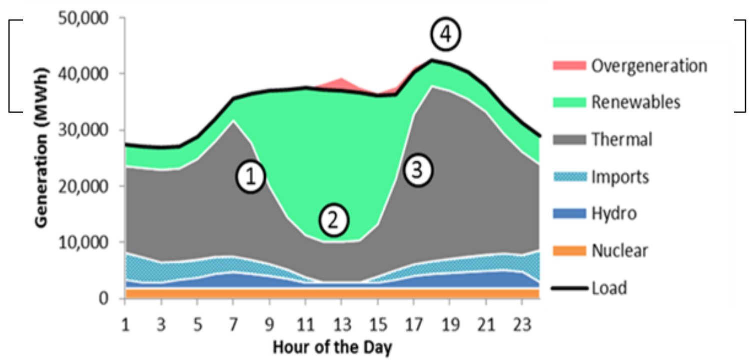
A significant resource that can provide DR services to the grid and contribute to its stability is agricultural irrigation pumping. Agricultural irrigation pumping is a significant component of California's electric demand. In addition, agricultural distribution feeders often have low diversity in their types of customer loads, and exercise of a large number of irrigation pumps on a single feeder can cause over-voltage issues (Olsen 2015). In 2016, the peak demand of the California's electricity grid was 46 GW (CAISO 2016). In the same year, the peak demand for agricultural irrigation pumping was 1.3 GW (3% of California's total peak electricity demand) (CAISO 2016). As of 2015, California Investor Owned Utilities' (IOUs) total DR portfolio added up to 2.1 GW (Alstone, et al., 2016). Theoretically, 62% of the current IOU DR portfolio can be satisfied through agricultural irrigation DR alone.

The changing picture; how energy demand and availability are changing;
With higher penetration of intermittent renewable sources, the grid needs to deal with generation variability. Intra-hour variability and short-duration ramps are one of the immediate challenges faced by a 50% renewable California grid. However, other challenges arise as the California grid becomes greener over time. Historically peak hours were defined as the hours between 12pm-6pm (PG&E, 2016). Proliferation of solar generation in California (especially rooftop solar) is forcing those peak hours to shift to later hours in the day (4pm-9pm)[4]. This is most commonly referred to as the "Duck Curve" (Figure 1), where the increased solar generation is significantly dropping the net electricity demand during the day, which in turn results in significant ramps in the later hours (CAISO, 2016).



The Duck Curve might be better explained by looking at the generation mix of California's grid under a 50% renewable portfolio standard (RPS) shown in Figure 2. In a 50% RPS scenario, thermal power plants will ramp down as solar resources come online early in the day (1). However, they cannot drop to zero since a minimum capacity need to remain spinning for contingency as well as the evening ramp up, and in the absence of cheap energy storage, excess solar generation must be curtailed to maintain grid stability (2). As solar resources stop generating electricity in the evening (3), thermal



[4] Although there are no updates to agricultural customer TOU periods, PG&E has announced new residential and commercial TOU rates with 3pm-8pm and 4pm-9pm as new peak hours.

power plants (mostly natural gas) need to ramp up to make up for the lost solar generation, and the evening ramp up will become more pronounced with increasing solar penetration (4).

Agricultural irrigation can help address several challenges highlighted in Figure 2. As shown in Figure 3, agricultural load is highly concentrated in the summer months, coincident with the peak demand of the grid as a whole. In addition, highest daily demand for agricultural irrigation occurs during hours with highest levels of evapotranspiration, which are coincident with highest levels of solar electricity generation. On the other hand, solar curtailment, whereby solar generators are disconnected from the grid to protect the grid from being overwhelmed, occurs between the hours of 12-6 PM, hours of peak irrigation demand.

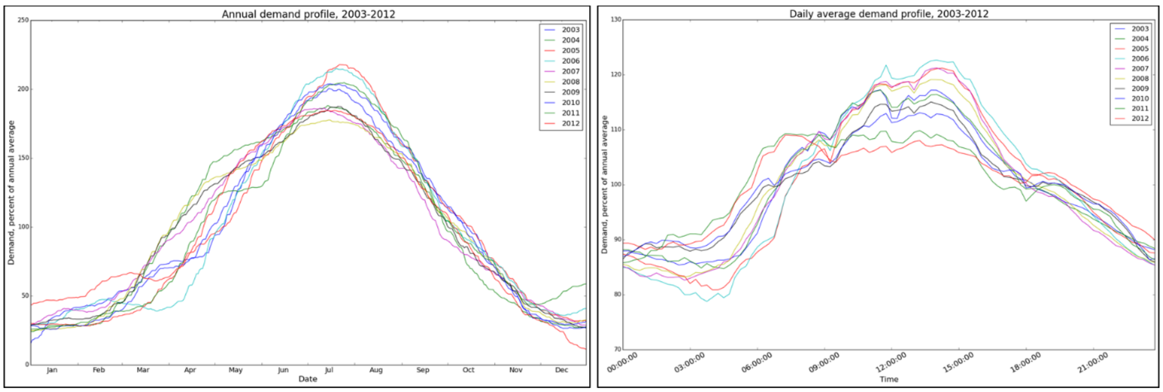


Figure 3: Estimated daily demand for a subset of PG&E agricultural customers, relative to daily average, 2003-12 (Left), and average daily demand profiles for interval meters, 2003-12 (right)

Therefore, a flexible and dynamic irrigation system can take excess load off the grid by over-irrigating during certain hours of the day (and less in other hours) in order to facilitate higher levels of solar integration into the grid and eliminate solar curtailment.

Most agricultural irrigation systems operate in a manual or semi-automated fashion which require long notification periods in order to participate in DR programs (Olsen 2015). A dynamic irrigation system (e.g. irrigation pumps equipped with variable frequency drives) can modulate its demand based on the instantaneous grid needs (e.g. variability of renewable generation) and provide fast response with shorter notification periods.

Currently agricultural irrigation pumping can only participate in traditional DR programs offered through utilities (also referred to as demand side DR). In the near future, fast responding DR services that can participate directly into the electricity markets will become more valuable. Automated DR (Auto-DR or ADR), another DR strategy in which loads are shed automatically in response to grid control signals unless the customer opts-out, allows quicker, more reliable load sheding with less effort required by grid operators and growers alike. ADR has the potential to be used for ancillary services, which are growing in importance due to the load uncertainty and variability caused by the integration of large shares of renewables (Watson et al. 2012). Such services are referred to as supply side DR. In order to provide supply side DR to the grid, loads should directly interact with the California Independent System Operator (CAISO). There are currently no mechanisms in place that allows pumping loads to directly provide supply side DR, so agricultural customers can only provide resources to the grid by enrolling in a TOU, DR, or ADR program offered by their local utility.

Time of use (TOU), demand response (DR) and automatic demand response (ADR) strategies; incentives/criteria/constraints; Time of Use (TOU) pricing is the most cost effective option for modifying load shapes because there are no site-level technology enablement costs and while the load reduction at any given site is typically small, the breadth of participation if the rates are default or mandatory provides a substantial statewide effect. TOU can contribute substantially to overall DR potential. The impacts of TOU pricing on agricultural accounts is clearly distinguishable in average daily demand profiles recorded by Pacific Gas and Electric's SmartMeters as shown in Figure 4.

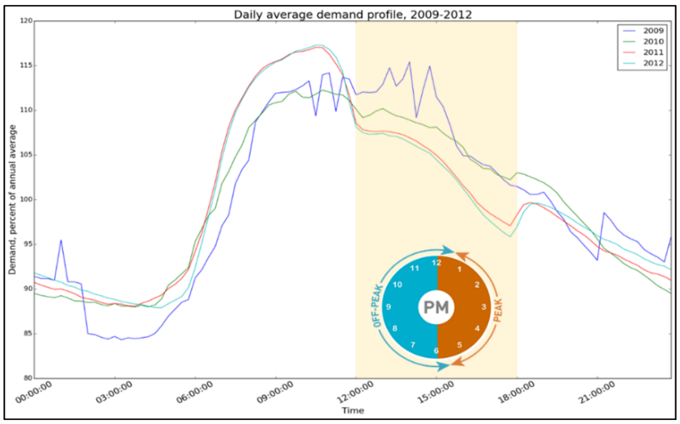


Figure 4: Average daily SmartMeters demand profiles, 2009-2012

In addition to TOU, several utilities offer various DR programs tailored toward agricultural irrigation customers with a combined load shed magnitude of 0.7 GW dating back to 2004 (Olsen 2015). Although largely successful, challenges faced by agricultural DR programs include unreliable shed rates (35%-85% relative to baseline load), low participation rates (20%), lack of automation, communications, and controls, as well as farm operational limitations (irrigation capacity, water delivery schedules, and labor).

Case-specific Illustrations of TOU and DR from cooperating farms

The examples presented below illuminate the nature of the demand management challenges from the irrigators' perspective. This limited overview of demand management for irrigated agriculture in the San Joaquin Valley illustrate the management decisions that must be made.

Example 1: Time of use management (TOU): The first case involves shifting time of use for a 92 acre almond orchard with ample delivery system capacity, a readily available water supply and on-farm water storage. The orchard is irrigated in three sets. Most irrigation events were 24 hours or more, so most irrigation events span three days. The actual sequence of irrigation dates and durations in 2017 is indicated by the darker histogram in Figure 5. The wide spacing between irrigation events indicates ample irrigation system capacity, allowing the farm to easily shift irrigation dates and durations. This represents an ideal opportunity for energy load shifting.

It is simple to plan and implement, and presents a clear financial benefit.

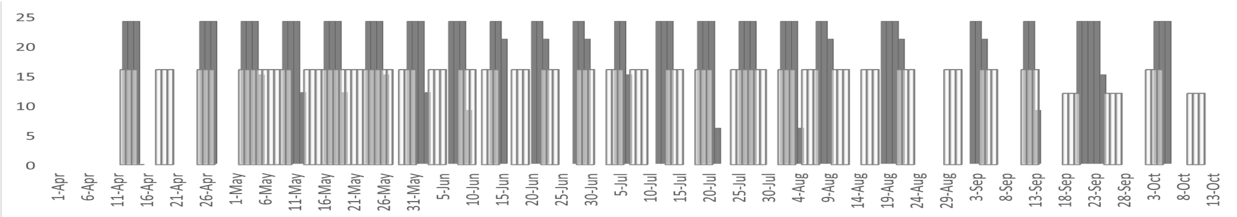


Figure 5: Alternative time of use (TOU) management

Energy rates for the farm are \$0.195 per kWh for off peak hours and \$0.445 per kWh for 8 peak hours daily. An alternative schedule, indicated by the lighter bars in Figure 5, would restrict irrigations to the 16 off-peak hours each day. The alternative schedule would have achieved virtually the same seasonal pattern of crop water availability as the actual schedule. Estimated pumping energy use in 2017 was 75 kW for 1908 hours, a total of 143 MWh. Pumping costs would then be \$39,681 for the actual schedule and \$27,834 for the off-peak pumping strategy. This simple TOU strategy would have achieved a saving of \$11,847 in 2017.

Example 2: Interruptible power and limited pumping capacity: Now let us suppose the same farm also participates in a DR incentive program involving interruptible energy use. If the farm were also following the above TOU schedule it will be operating close to maximum pumping capacity. The incentive program stipulates that interruptions will last no more than four hours, with no more than one interruption per day nor more than ten per month. The analysis begins with the irrigation schedule based on 16 hour sets presented in the previous example (the darker bars in Figures 5 and 6). A modified schedule with occasional interruptions generated at random times is overlaid on the intended schedule (the lighter bars in Figure 6). An energy interruption is represented as a gap in the lighter bars. If an interruption is called when no pumping was planned it is indicated as a negative four-hour bar. On those days when no pumping was planned additional pumping for 8 to 12 hours can be inserted to compensate for up to preceding interruptions.

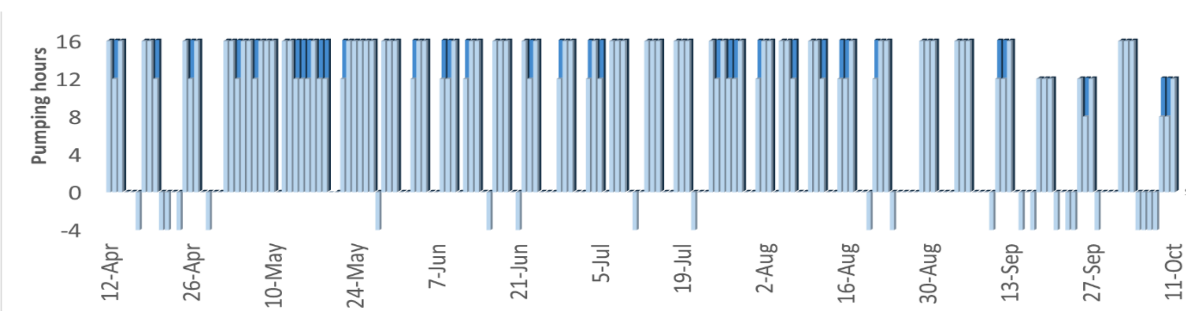


Figure 6: combining TOU and DR management

It appears from Figure 6 that the irrigator could compensate for most interruptions shown in by shifting irrigation dates by a day or two. Estimated impacts of such limited delays on crop production should be minimal (as will be discussed in the following example).

This example can also illustrate an important constraint common to demand response programs, which is that a farm shall only be compensated for DR participation in months when they would normally be using a significant percentage of pumping capacity. For example, the requirement might stipulate that the farm would normally be irrigating 75% of the time. In this case the TOU seasonal pumping from May through August would exceed the 75% level. If the financial incentive for participating in the DR program were $8 per kW per month and the farm qualifies for four months the payout would be an additional $2400 per year. However it is important to note that interruptible energy use could entail capital investment for remote system control and variable speed pumping, which are not considered here.

Example 3: Yield impacts of interruptions: Figure 7 shows a schedule for another orchard in which a similar TOU strategy was developed for a maximum of 15 off-peak hours per day. However, in this case the irrigation capacity could not meet scheduled crop water demands on six dates in late July and August, indicated by negative bars, each representing 15 hours of additional pumping needed to maintain the intended soil moisture pattern. The cumulative irrigation deficit during that interval would be 6% of intended seasonal water use.

Scheduling of additional irrigations to compensate for the 6% deficit would involve significant shifts of in the timing of applied water. Compensating irrigations will necessarily be delayed by two weeks or more until late August. Additional irrigations that late in the season will not mitigate the month long period of stress from mid-July to mid-August.

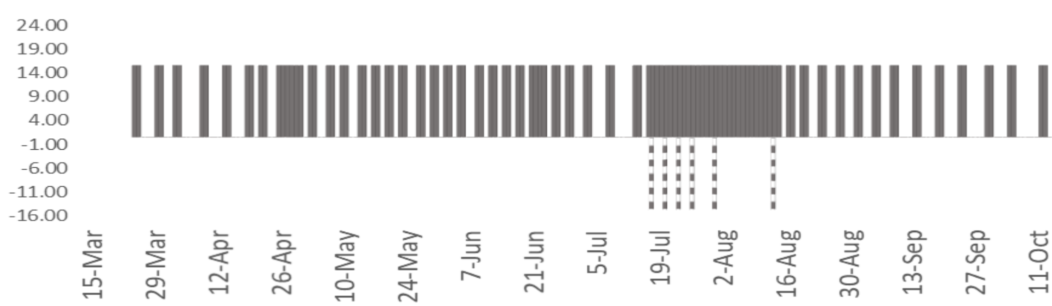


Figure 7: Deficits caused by pumping interruptions

The consequences of such periods of stress will depend on the complex relationships between irrigation timing and amounts, crop water availability and crop response to available water. The ability of a crop to recover from a delayed or missed irrigation will depend on the stage of growth, the reserves of water in the soil, atmospheric conditions and the physiology of the crop.

In this case we used an advanced irrigation management model, discussed later in this paper, to estimate the effect that reduced crop water availability would have on the cumulative daily ET. ET deficit is a widely used parameter for estimating yields under limited irrigation conditions. Figure 8 shows estimated daily ET for the two alternative irrigation schedules, indicating an ET deficit until August 20. The resulting cumulative ET deficit reached a maximum of 0.45 inches, approximately 1% of normal seasonal ET, before the compensating irrigations began. Because that deficit is concentrated in a one month interval it would represent a 4% ET deficit roughly coinciding with the onset of harvest, which could result in a more significant effect on yields. On the other hand, some degree of deficit irrigation may actually increase farm profits by reducing costs and increasing management flexibility. Modeling of the impacts of ET deficits is therefore a central issue for DR management.

Figure 8: Comparison of estimated crop ET under alternative management scenarios

Example 4; Conjunctive management of multiple fields: Figure 9 illustrates the greater complexity involved in conjunctive management of multiple fields. Figure 9 shows pumping demand for four fields on another cooperating farm in 2017. The stacked bars represent hours of pumping in each of the four fields. The highly irregular pattern indicates this farm could reduce peak demands substantially by shifting most irrigation dates by a day or two.

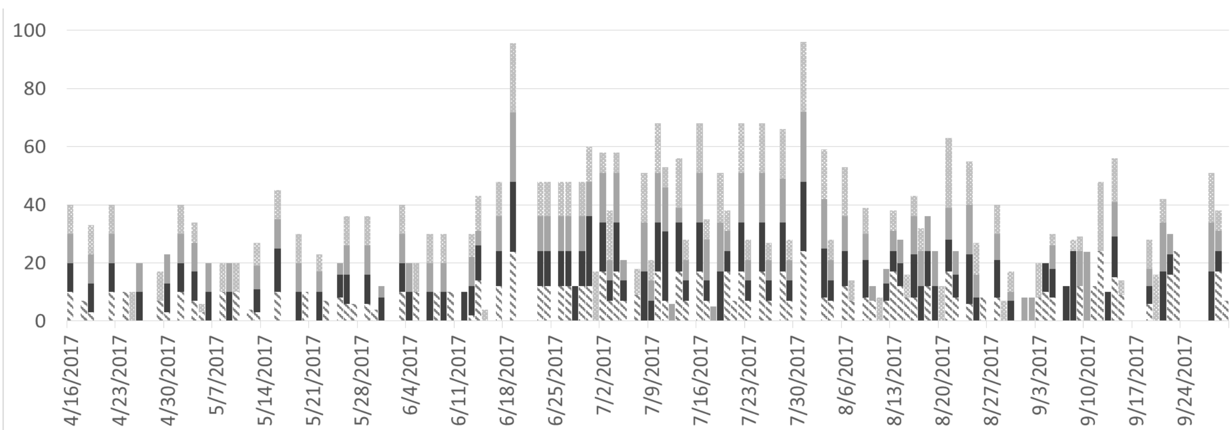


Figure 9: Conjunctive management of four fields

However such re-scheduling can be complicated by the need to re-allocate limited water among different and competing applications, such as different crops, differences in field characteristics (e.g. soil parameters) and differences in irrigation system characteristics in the different fields.

A decision support system to facilitate demand management

As indicated above, irrigation planning to accommodate TOU and DR strategies will need to anticipate occasions of high water demand weeks or months ahead of time, especially when allocating water among multiple fields that share a common water supply. If optimal water use involves some degree of deficit irrigation, the planner will need to assess the possible yield impacts of delaying, reducing or eliminating some irrigations.

Meeting these challenges will require accurately modeling the disposition and fate of applied water over extended periods of time and modeling crop response to available soil moisture. And long range plans need to be easily and quickly updated when and as changing weather, the availability of water, disease problems and other factors evolve during the season. And planning needs to account for farm-specific constraints due to contractual arrangements, operating practices, risk tolerance and other factors that differ from one farm to another.

Current irrigation management technologies, which focus on monitoring current conditions and simple water balance modeling does not provide adequate support for such management challenges. The CEC is therefore funding adaptation of an existing decision support system. Known as *Irrigation Management Online* (IMO), the system was originally designed for optimal long range planning and management of irrigation strategies, including deficit irrigation, to deal with these complex management challenges (*Hillyer at als, 2015*). IMO utilizes comprehensive and sophisticated modeling of the disposition and fate of applied water in order to accurately project crop water availability well into the future. The software maximizes analytical efficiency and speed to minimize the computational burden in order to facilitate iterative analysis of alternative management practices under variable and uncertain field circumstances.

The IMO system supports five phases of irrigation management;

- *Planning seasonal water use*; consulting with the farm manager is an essential first step to account for the manager's prior experience, tolerance for risk or uncertainty, contractual arrangements, incidence of disease or pests and other ancillary factors that influence irrigation management. Researchers and extension leaders are also consulted to identify the best seasonal pattern of water use based on local field circumstances.
- *Seasonal scheduling;* generating a full season irrigation plan, with anticipated dates and set times for all irrigation events to implement the intended seasonal pattern of water use (as illustrated in Table 1).
- *Dynamic scheduling;* tracking measured and estimated soil moisture (illustrated in Figure 10) and updating the irrigation plan continuously to account for actual seasonal weather, changing farm objectives or other changing circumstances.
- *Recalibration;* using incoming field data to check the accuracy of the analysis and recalibrate model parameters.
- *Yield modeling;* in some applications water use and crop yield data have been combined to calibrate a farm-specific crop yield models for estimating yield deficits (see Example 3).

Start Date	Gross Application (inches)	Set/Block/ Rotation (hours)
7-Apr	1.91	28
17-Apr	1.91	28
24-Apr	1.91	28
1-May	1.63	24
8-May	1.91	28
15-May	1.91	28
22-May	1.91	28
29-May	1.91	28
5-Jun	1.91	28
12-Jun	1.63	24
19-Jun	1.63	24
26-Jun	1.63	24

Table 1: a seasonal irrigation schedule

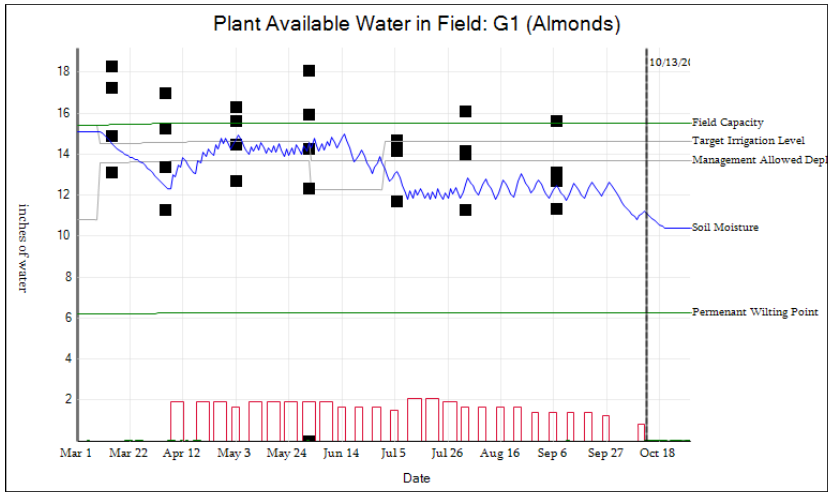


Figure 10: estimated and measured soil moisture

Two additional algorithms are being developed to simplify use of the IMO system. The first, an auto-scheduling algorithm, will automatically generate an irrigation schedule for an upcoming season and update the schedule quickly when circumstances change. If an interruption in a planned irrigation schedule renders the original schedule infeasible, as illustrated in Example 3, the algorithm will generate alternative new schedules, reject schedules that violate operational constraints, evaluate the outcomes of feasible schedules in terms of a specified objective function, and repeat this sequence in a systematic search for a 'best' schedule.

The second new algorithm will automate the process of re-calibrating the analytical engine, a procedure that currently depends upon a trained analyst. We are currently in the conceptual development phase, exploring alternative machine learning tools and formulating specifications for the objective function[5].

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2018 Poster Abstracts

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UNDERGRADUATE STUDENT POSTERS

1.

Water Stress at Vegetative Stage of Corn and Sorghum can Improve their Drought and Heat Tolerance during Flowering and Yield Formation

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Global yield loss of major food crops due to abiotic stress is estimated to be more than 50%. Considering that climate changes has increased the intensity and frequency of stressful conditions, flexible approaches are needed to mitigate the impacts of abiotic stress on crop yield. This study aimed to investigate the possibility of increasing the corn heat and drought tolerance by imposing them to a mild drought stress during their juvenile stage.
A field trial was established at the California State University- Chico Farm in 2017. Four treatments of 1) fully irrigated control, 2) preconditioned (drought at vegetative stage) only, 3) preconditioned and drought stress at flowering, and 4) drought stress at flowering only, were applied. Root area and root thickness, stomatal conductance, NDVI, and leaf surface area were quantified throughout the season, and forage yield was measured at physiological maturity. Exposure of young plants to drought (preconditioning water stress) reduced the height, NDVI, leaf surface area, and forage yield of corn and sorghum. However, water stress at vegetative stage reduced the negative effects of drought at reproduction stage. Preconditioned plants produced higher yield than the plants under treatment 4 (stressed at flowering only). During the hot days of August when temperature exceeded 40°C, preconditioned plants kept their stomata open and maintained a high CO_2 exchange rate compared to the fully irrigated plants. These preliminary results align with previous findings that recommend a mild stress at the young stages can help reducing the impacts of stressful conditions at reproduction and yield formation stage.

2.

The effects of nitrogen fertilizer on alfalfa yield production

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Response of alfalfa to nitrogen (N) fertilizer was studied in two experiments at California State University, Chico. In experiment one, alfalfa yield in response to four rates of N after cutting was measured. Seeds were inoculated with a commercial rhizobia inoculant and planted into plug trays in the greenhouse. Seedlings were transplanted into 5-gallon buckets filled with a mixture of soil, sand, and peat moss, and placed in an open field. All pots received macro- and micro-nutrients, plus 0.9 g urea pot^{-1} (equivalent to 30 kg ha^{-1}) as starter N at planting time. The N application was started after the first cut. Plants received four levels 0, 0.9, 1.7, and 3.5 g urea fertilizer per pot (equivalent to 0, 30, 60, and 120 kg N ha^{-1}) with the first irrigation immediately after each cut. On average, alfalfa produced 23, 21, 14, and 23 g pot^{-1} dry mass in cut 2, 3, 4, and 5, respectively. Averaged across the cuts, alfalfa produced 22, 37, and 49% more yield in N30, N60, and N120 respectively than in the control (0N).
In the second experiment, the effect of starter N after cutting on alfalfa yield was measured. Seeds were inoculated with a commercial rhizobia inoculant and sown into 6" pots, filled with N-free media (equal ratios of vermiculate, perlite, and sand). Phosphorus, potassium, and micronutrients were supplied by commercial fertilizers at planting, and plants were watered daily by deionized water. N treatments (1 g urea pot^{-1}) included: 1) 0N, 2) N after cut 1, 3) N after cut 2, and 4) N after cut 1 and 2. Alfalfa yield in the third cut was 2.6 g plant^{-1} (0N), 3.6 g plant^{-1} (N after cut 1), 4.6 g plant^{-1} (N after cut 2), and 5.2 g plant^{-1} (N after cut 1 and 2). The results of both experiments suggest that alfalfa yield can benefit from additional N after cutting. Further investigation needed to confirm the results in the field.

3.

Chlorophyll Content for Lettuce Subjected to Two Irrigation Regimes, and Four Different Organic Fertilizers and Rates

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In an effort to optimize fertilizer use efficiency in short season vegetable crops, such as lettuce, organic growers are interested in knowing how various commercially available OMRI listed fertilizers influence plant growth. By using the SPAD Meter to measure the chlorophyll content within the lettuce leaves, we can indirectly estimate photosynthesis rates, and thereby infer the plant's metabolic activity. This study focused on determining the effects of irrigation regimes, organic fertilizer types, and fertilizer application rates on plant chlorophyll content of lettuce. The experiment was a strip split block design with two irrigation treatments (main factor), four fertilizer types (Bone Meal, Guano, Fish Meal, and Feather Meal as the sub plot factor) and four rates of nitrogen fertilizer (sub-sub-plot factor) with four replications. SPAD readings were taken at different growth stages of lettuce during two separate greenhouse trials using a sandy loam soil. Irrigation and fertilizer rates for the first trial had a significant impact on lettuce chlorophyll content, with SPAD reading at 80% ET irrigation being significantly higher than that of 100% ET ($p = 0.051$ *and* 0.026). SPAD readings for the control fertilizer treatment (0 lbs N/acre) were significantly less than the other fertilizer rates (60, 120, and 180 lbs N/acre) ($p = 0.010$ *and* 0.00), with 180 lbs N/acre yielding the highest leaf chlorophyll content. In the second trial, a significant difference in the chlorophyll content due to irrigation rates was only observed near harvest date ($p = 0.068$). I contrast, significant differences in chlorophyll content due to fertilizer rates was only detected at the first SPAD reading ($p = 0.009$). Fertilizer types had a significance impact on plant chlorophyll content for two of the three SPAD dates ($p = 0.020$ *and* 0.040), and a Fertilizer x Irrigation interaction effect was detected for some of the dates.

4.

Corn root growth and yield in response to phosphorus solubilizer inoculants in northern California

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Beneficial microorganisms can improve soil health and contribute to increased crop production. From commercialized microbial products, phosphorus (P) solubilizers can enhance plant P uptake and yield by adjusting the pH of soil rhizosphere, and by stimulating root growth rate. Improved P availability, which is strongly limited by several soil factors, can increase the nutrient use efficiency and crop yield. A field trial was conducted at the California State University - Chico Farm to investigate the effect of Quickroots® (Monsanto BioAg, MO), BioOrganics ™ Endomycorrhizal Inoculant (Bio Organics™, PA), and a mixture of these two inoculants on root characteristics, growth, and yield of corn. Corn seeds were inoculated with the products and sown directly into an Almendra Loam soil following a fababean cover crop. Leaf nitrogen was estimated using a SPAD chlorophyll meter, root characteristics (thickness and surface area) were quantified using the WinRhizo Software (Regents Instruments, Quebec, Canada), and arbuscular mycorrhizal (AM) fungi infection was quantified as the percentage of root colonized by AM fungi.

The results suggest that microbial inoculants had little effect corn growth (plant height), leaf chlorophyll concentration (SPAD values) and silage yield. On average corn produced 28% and 24% more silage in response to Quickroots® and Endomycorrhizal Inoculant than the control, respectively; however, the differences were not significant. Similarly, variations of leaf chlorophyll content, plant height, and root parameters due to the treatments were not significant. Interestingly, root infection by AM fungi was minimal across all treatments. The absence of AM fungi from the roots might be associated with high levels of available P in the soil. These results suggest that in addition to cultural practices such as tillage that disturb soil microorganisms and lower their benefits, nutrient management can impact the benefits of soil microorganisms in cropping systems. Additional works need to quantify the presence and effect of AM fungi on crop yield under various cropping systems and nutrient management.

5.

Performance of Flax as a Winter Fiber Crop in Northern California

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Flax is a versatile ancient crop that has been grown worldwide for thousands of years. Two major types of flax include oil (or grain) varieties, which are relatively short and branched, and fiber varieties, which are tall and have single stem. Both flax types, especially the fiber varieties, are planted very dense (in 6” rows) and can smother weeds once the crop established. Flax is a cool-season crop with a relatively short growing season that can fit into most cropping systems. In northern California and similar climates, flax can be grown during the cool season of fall to spring, when irrigation requirement is minimal.

In the past 5 years, Chico Flax has been testing the performance of flax varieties that can economically produce fiber for linen yard in Chico. We aim to secure funds and expand the research and test the potentials of flax as a winter fiber crop in northern California. In this particular project, we are testing the performance of five fiber flax varieties, including Calista, Vesta, Melina, Marilyn, and Arbutus. The varieties were established in a completely randomized block design with three replications on November 18. Seed germination was recorded two weeks after the sowing. Normalized Difference Vegetative Index (NDVI) has been measured as an indirect measure of plant growth and biomass accumulation, using a greenseeker. On average, the Arbutus variety had 30% higher germination and tend to have higher NDVA than other varieties. Collected data will be presented in more details in the poster, and the experiment will be concluded in the spring.

6.

The Comparison of Compost, Fertilizer and Endomycorrhizae Inoculant effects on Development and Yield Production of Glacier Tomato Plants in California

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Endomycorrhizae is hypothesized to have a mutualistic symbiotic relationship with a variety of plant life. Assessing the overall effects of Endomycorrhizae on crop development can provide useful insights on how to efficiently maximize crop yields. Tomato bush Glacier (*Lycopersicon lycopersicum*) variety produces sweet, small tomato fruits from spring through fall. Production in Northern California is available for extended period of time providing farmers with higher yield. BioOrganics TM Endomycorrhizal Inoculant was applied on half of the planted tomato plants, the other half represented control group without inoculant application. Initial germination and seedling growth occurred in a controlled greenhouse environment. After four weeks, seedlings were measured and transplanted into garden pots, where the inoculation was given. The media used contained 1/3 topsoil, 1/3 sand, and 1/3 pro-moss soil mixture. Half of the inoculated and control specimens received Gardener's cow manure compost application, and second half received Osmocote fertilizer. Fertilizer had equal amount of three main macronutrients (N, P and K) with fertilizer grade 14-14-14. Compost and fertilizer were re-applied after 4 weeks. Plant height, root size, flower production, and fruit production and weight were recorded. Compost inoculated tomato plants showed improved growth compared to control plants. Inoculated tomato plants were taller, recorded larger roots, with more flowers produced per plant, and higher overall fruit yield. Fertilizer inoculated tomato plants had initial heightened growth and flower production. However, once the fertilizer effect disappeared control plants demonstrated better results in height and yield production. To conclude, mycorrhizal application positively affects the root growth and higher yield production. Based on greenhouse and garden pot growth, suggestion is to use compost instead of fertilizer to achieve the best results.

7.

Growth rate and Yield of Kale Intercropped with Fennel, Cilantro, and Mustard

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Intercropping is defined as growing two or more plant species at the same time in the same space. Intercropped plants occupy different ecological niches, complement each other, and utilize soil and atmospheric resources efficiently. It is also believed that intercropping can benefit the yield by reducing the pest and disease pressures. In this study, we are measuring the yield (production) of kale (*Brassica oleracea*) intercropped with three companion crops of fennel (*Foeniculum vulgare*), cilantro (*Coriandrum sativum*) and mustard (*Brassica sinapis*). Each plot consists of two rows of kale (outside) and one middle row of the companion crop. The experiment has been established in the Organic Vegetable Garden at CSU Chico Farm in a completely randomized design with three replications. Current data collection includes weekly measurement of the Normalized Difference Vegetation Index (NDVI) by a greenseeker, as an indirect estimate of plant biomass accumulation. At the end, crops will be harvested and total production and the land equivalent ratio (LER) will be calculated. Preliminary NDVI observations show that the combination of kale and mustard has the largest leaf area (the highest NDVI values) among the treatments. Average NDVI values from the first greenseeker reading on January 12 was as follow: kale and mustard 0.385, kale and fennel 0.301, kale and cilantro 0.278, and the control (kale only) 0.253. The results will be presented with more details in the poster.

8.

Leaf and Soil Nitrate Levels for Lettuce Subjected to Two Irrigation Regimes, and Four Different Organic Fertilizers

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Nitrate and irrigation management is essential for the sustainability of crop production, especially in organic agriculture. Two greenhouse lettuce trials, using a sandy loam soil, were conducted during the summer of 2017 to assess the impact of irrigation regimes and organic fertilizers on the nitrate levels in lettuce leaves and in the soil. Treatments consisted of two irrigation regimes (80% ET and 100% ET), and four organic fertilizers (Bone Meal, Guano, Fish Meal, and Feather Meal), applied at four application rates (0, 60, 120, and 180 lbs N/acre). Results from the first experiment indicated that tissue nitrate at 80% ET were statistically higher than concentrations observed at 100% ET ($p = 0.002$). Nitrate concentration in leaf tissues was also highly influenced by fertilizer rates ($p = 0.000$) with the control treatment (0 lbs N/acre) having the lowest concentration, and 180 lbs yielding the highest. A similar trend was observed in the in post-harvest soil samples ($p = 0.005$). Irrigation and fertilizer types did not affect post-harvest soil nitrate ($p < 0.05$). Irrigation did not have a significant impact on tissue nitrate during the second trail, even though we observed that nitrate concentration in 80% ET was higher than that in 100% ET. Fertilizer rates on the other hand did have an impact on tissues nitrate ($p = 0.000$), with plants from the control plots having significantly less nitrate than those receiving the 60, 120, and 180 lbs of N/acre. Irrigation and fertilizer rates both had a significant impact on post-harvest soil nitrate ($p = 0.021$ and $p = 0.000$), with higher nitrate concentration again at 80% ET compared to 100% ET.

9.

Can herbicide Yield Drag be reduced with a foliar amendment?

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Yield drag (YD) is the result of something that reduces optimum productivity. YD attributed to Roundup herbicide has been a controversial topic. If real, could YD be mitigated by the addition of a bio-stimulant? A field trial and greenhouse study were conducted to evaluate this question. The field trial was in a production Roundup Ready Alfalfa field near Riverdale, CA and the greenhouse pot study, using the same variety was conducted at Fresno State facilities. The material used to test for YD mitigation was CHB-6010, a foliar nutritional fertilizer. Foliar treatments were of varying rates of CBH-6010 with and without Roundup. Samples were collected at 7 and 14 DAT intervals for crude protein, TDN, ADF, and dry matter yield. The field trial results were influenced by the effectiveness of the Roundup to control weed over the non-Roundup treatments. The first cutting results indicated a positive treatment response compared to the final (3rd) cutting that had the highest weed pressure. In the greenhouse study, parameters that affected the field study were removed and allowed a sharper focus on plant response to the Roundup. The quality parameters varied due to the vegetative stage of the alfalfa. However, dry weights of harvested shoots and roots show clear differences between the Roundup treatments compared to the non-Roundup treatments. Our results indicated that even a Roundup tolerant variety experienced a decrease in shoot and root dry weights from a Roundup application. Results also show the herbicide caused Yield Drag was reduced by the foliar application of CHB-6010, and some measured quality parameters improved over the untreated control and the Roundup treatments.

10.

Potentials of Fababean as a Dual-Purpose Cash & Cover Crop in Northern California

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Fababean (*Vicia faba*) is one of the oldest field crops grown around the world for dry beans and green pods. Because of its substantial biological nitrogen (N) fixation and N benefits to soil, fababean is extensively promoted as a winter cover crop mix in California. Considering that land costs, seed and planting operation are some the major obstacles of cover cropping, we aim to identify some economic benefits of fababean that can enhance its cultivation. Fababean green pods and immature seeds are consumed by Hispanics (and other ethnicities) in the United States. The pods are also popular in other countries. This market offers potentials to increase the economic benefits and cultivation of fababean as a dual-purpose cash/cover crop in northern California. Two field trials were conducted at 1) a grower's field and 2) at CSU-Chico Farm in the growing season of 2016-17. At the grower's field, a large-seeded indeterminate variety was planted in the fall, and pods were hand-harvested during the March, April, and May of 2017. The crop produced a total of 5600 kg fresh pods ac^{-1}, and generated a gross income of \$9000 and a net benefit of \$3000 ac^{-1}. Although the crop's N benefit was not quantified, it is expected that it added 60 to 90 lb N ac^{-1} to the soil. In the second trial, the fababean germplasm, consists of 375 genotypes, was obtained from the Germplasm Resources Information Network and sown at two dates (Sep 20 and Oct 20, 2016). Morphological characteristics related to the pod production potential of the plant population will be presented in more detail.

11.

The Response of glyphosate resistant Junglerice to temperature and dose response

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Echinochloa colona (junglerice) is a summer annual grass belonging to the Poaceae family. It has been ranked among the world's top ten worst weeds. In recent years, glyphosate-resistant (GR) biotypes of junglerice have been documented in various parts of the Central Valley of California. Previous research has identified several different target site mutations causing around a four-fold level of resistance as well as the likely presence of a non-target-site mechanism. Another previous study suggested that the growth response to environmental stochasticity varied among GR biotypes. Because of the suspected non-target site mechanism of resistance and the observed responses to environmental conditions under no-glyphosate conditions, this research focused on the interaction of glyphosate dose and temperature on the response of several known glyphosate-resistant and glyphosate-susceptible junglerice populations from California orchard crops. Plants were treated at the three to four leaf stage with a range of glyphosate doses (0, 0.5, 1x) using a greenhouse air-pressurized cabinet sprayer calibrated to deliver 20 GPA. After application, plants were transferred to controlled environment chambers set at 20C, 30C, or 40C with metal halide lighting. Each biotype x glyphosate dose x temperature treatment combination was replicated five times. Glyphosate activity and plant growth and mortality data were monitored over a 21-day period. Shikimic acid accumulation was evaluated in plant tissues at 6, 24, 48 and 72 hours and after treatment to determine relative inhibition of the target enzyme. Aboveground plant biomass was harvested 21 days after treatment, dried and weighed. None of the glyphosate-treated susceptible junglerice lines survived at any of the temperature regimes tested. Based on visual evaluation the GR plants were stunted by glyphosate treatment in the cooler environments; however at higher temps little or no stunting was observed even at the highest rate. These results were supported by the differential accumulation of shikimic acid in GR and GS lines at different rates and temperatures. These results suggest that temperature can influence glyphosate activity on GR Echinochloa colona which may help explain the variability occasionally observed in the field.

GRADUATE STUDENT POSTERS -- M.S. candidates

1

Nitrate Leaching and Water Management in Lettuce

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Limiting nitrate leaching requires not only a reduction of added nitrogen (N) but judicious use of irrigation. The overall goal of our on-going research is to optimize nitrogen use efficiency and water use efficiency in vegetable production. In this phase, the objective was to assess the potential for nitrate leaching for a lettuce crop subjected to three irrigation regimes and four fertilizer N rates. Butterhead lettuce (*Lactuca sativa* cv Optima) was planted on a sandy loam soil at Fresno State, on 60-inch beds with three rows per bed and intra-row spacing of 12 inches. The experimental design was a strip block with four replicates of three irrigation treatments (manual, CIMIS, and water moisture content sensors) and four rates of N fertilizers (0, 60, 120, and 180lbs N/ac of CAN17). At harvest, both irrigation ($P=0.02$) and fertilizer ($P=0.08$) had a significant effect on above ground biomass. The plots irrigated manually and with 100% ET based on CIMIS irrigation scheduling yielded higher biomass than the plots in which irrigation scheduling was based on soil moisture sensors. There was a positive fertilizer response, best described by the polynomial equation $y = 1E\text{-}06x^3 - 0.0003x^2 + 0.0303x + 1.658$ ($r^2 = 1$), with an overall 46% increase in biomass with the addition of 180 lbs of N/ac. Both fertilizer and irrigation treatments had a significant effect on petiole nitrate levels, with the manually irrigated plants having the highest nitrate content followed by soil sensor based and CIMIS scheduling, respectively. Fertilized plants had nitrate concentrations greater than 6000ppm which is above the sufficiency level reported for lettuce. In the top 12 inches of soil, fertilizer rates had a significant ($P=0.0002$) effect on post-harvest nitrate levels, with values in excess of 40ppm in the plots receiving 120 and 180 lbs N/ac, and 17ppm in the 60 lbs N/ac plots, compared to less than 2ppm in the unfertilized plots. These preliminary results further validate the need to quantify biomass yield and nitrate concentrations plant and soil, if an N- balance approach is to be adopted in an effort to mitigate nitrate leaching.

2

Evaluation of isolates of Fusarium oxysporum f. sp. vasinfectum causing seedling disease to cotton

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Fusarium oxysporum f. sp. *vasinfectum* (FOV) race 4 is an extremely virulent fungal pathogen that causes wilt disease to susceptible varieties of cotton. Within the United States, FOV race 4 currently is geographically limited, and was first identified in the state of California in 2001 and in Texas in 2017. In FOV race 4-infested fields the fungus has also been known to cause early damping off and seedling mortality. To better assess disease impacts under California field conditions, more needs to be known of the relative pathogenicity of FOV races as seedling pathogens. Therefore, the objective of this study was to assess the reaction of cotton to seedling infection by different isolates of FOV. During the summer of 2017, isolates of FOV were isolated from infected cotton seedlings from three FOV race 4-infested commercial fields across the San Joaquin Valley of California. To test isolate aggressiveness a rolled towel assay was used to evaluate 16 isolates of FOV. Seeds from the FOV race 4-moderately resistant Upland cultivar FM-2334 were individually inoculated with 100 µl of a 1×10^6 conidia/ml suspension. At ten days, seedlings were rated using a disease severity index (DSI) and an ordinal rating scale (1= no disease, 5= dead). Based on DSI and ordinal rating scale, seven isolates were significantly different from the non-inoculated control ($P<0.05$). The DSI average for these isolates ranged from 34.8-43.8% and ordinal rating averages ranging from 3.08-3.37. Based on these results, more emphasis should be placed on seedling diseases in cotton when developing resistant varieties and the use of the rolled towel assay should be examined as an early screening method.

3

Weed vs. Crop Differentiation Using Crop Marking Systems

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Increasing weed control costs threaten vegetable crop grower profitability due to labor shortages, rising labor expense, as well as lack of and loss of herbicides. Automated weed control systems can help to contain or decrease weed control costs. Traditional inter-row mechanical cultivation is not sufficient, as it does not remove weeds within the seed line at early growth periods when competition for nutrients, water and light is critical. Thus, intra-row hand weeding is necessary, but increasingly expensive. Current intra-row weeders commercially available do not differentiate between crops and weeds, but rather rely on row pattern recognition. The row-pattern recognition systems are problematic where weed populations are high and the row pattern cannot be detected. In these weedy situations, the machines cease to function or cause damage to the crop. Two methods were tested to differentiate crops from weeds and so they could be detected by a mechanized weeder: 1) Topical Markers and 2) Plant Labels. Field trials were conducted in 2016-2017 on seeded lettuce at the USDA-ARS Salinas research station and on processing tomatoes at UC Davis using topical markers (orange fluorescent paint) and plant labels (biodegradable straws painted fluorescent green or orange). Weed reductions of 60-80% were achieved with the automated cultivation compared to standard mechanical cultivation. Significant reductions in both weed densities and manual labor can be achieved with an automated weed control system in comparison to standard cultivation. Weed control in close proximity (less than 1 inch) to crop plants may still require limited manual labor or herbicide application.

4

Landing rate of the walnut twig beetle, Pityophthorus juglandis, on two western North American walnut species, Juglans californica and J. major

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The walnut twig beetle (WTB), *Pityophthorus juglandis*, vectors a phytopathogenic fungus, *Geosmithia morbida*, which causes Thousand Cankers Disease (TCD) in walnut trees, *Juglans*. We are investigating the susceptibility of two walnut species native to the western USA (*Juglans californica* and *J. major*) by comparing the WTB flight and landing responses to small diameter branch sections. Twenty unbaited branch sections (10 each) were presented in a completely randomized design to a population of WTB at Wolfskill Experimental Orchards (Winters, California) and the Agricultural Teaching and Research Center (ATRC) in Chico, California. Stickem-coated acetate sheets were placed around the branch sections and exchanged weekly. Three trials were completed in Wolfskill (Trial 1-3), and one trial was completed in ATRC (Trial 4). Landing rates on these traps were compared between *J. californica* and *J. major*. An additional trial (Trial 5) was completed at the Wolfskill site to measure responses to *J. californica* and to a cardboard tube (negative control). More WTB were captured during the spring trials at Wolfskill (1 and 3) than during the fall trials (2 and 5), and more WTB were captured during the Wolfskill trials than during the ATRC trial (4). Female catch always exceeded male catch. However, neither trial showed a strong preference by WTB males or females for one host over the other. The overall mean of WTB landing on unbaited branch sections of *J. californica* and *J. major* ranged from 0 to 3 beetles (per week) and the range for the control was from 0 to 0.4. Trials 1-3 indicate a slight preference by WTB for *J. californica* over *J. major*. Trials 4 and 5 indicated no preference.

5

Improving Nitrogen Use Efficiency in Sugar Beet Production with Deficit Drip Irrigation

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Since the early 1980's, more than 3 million acres of California farmland have been converted from flood to drip practices. Numerous studies have shown that converting from flood to drip irrigation can increase crop yield as well as nitrogen use efficiency (NUE). Sugar beets, an important source of domestically produced sugar, solely utilize traditional flood practices. Thus, the objective of this study was to determine if transitioning sugar beet production to drip irrigation could improve NUE. The experimental design was a split-plot with three replications of irrigation as the main treatment (100% ET surface-drip, 70% ET surface-drip, and 100% ET flood) and nitrogen rate as the sub-treatment (0, 100, 150, 200 lb N/ac). Results from our 2015 and 2016 growing seasons revealed a highly significant interaction ($p=0.012$) between irrigation and fertilizer treatments. This interaction was well demonstrated in the soil depth analyses which linked higher soil nitrate concentrations to a reduction in irrigation water applied. During both growing seasons, a strong interaction ($p=0.016$) between nitrogen rate and soil depths was also detected. The increase in fertilizer applied resulted in a decline of soil nitrate levels at all depths. Although the petioles did not show any statistical differences among treatments, the average root nitrate concentrations for both growing seasons were higher in the 70% drip treatments compared to the 100% drip treatments. The greatest NUE was observed for sugar beets receiving 100 lb/ac Nitrogen fertilizer with values of 0.26 and 0.32 tons/lb N for 2015 and 2016, respectively. There were no statistical variances in yield among treatments. These results suggest that deficit drip irrigation coupled with reduced nitrogen rates can provide equivalent yields while maximizing NUE.

6

Predicting Nitrogen Mineralization in California Agroecosystems

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After decades of fertilizer use, California is now facing growing concerns over groundwater quality. To remain competitive, growers must apply nitrogen (N) fertilizers at sufficient rates to reduce risk and maximize yields. Often, however, N released from mineralization (N_{min}) of soil organic matter (SOM) is not considered when determining N budgets. To date, there are a lack of rapid, dependable tools available for accurately predicting N_{min} in California. Many methods for assessing N_{min} are costly and time consuming and integration of models from other locales is futile as studies have shown they must be regionally specific. A promising solution, however, lies in relating soil properties to N_{min} within specific regions. Many soil properties are easily measured and change little from year to year. In this study, N_{min} rates for 57 soils across California were measured by incubating 4.5 x 15 cm undisturbed soil cores for 10 weeks at 3 temperatures: 5, 15, and 25 °C. Numerous soil properties were measured and stepwise multivariate regression was used to generate a predictive model. Greenhouse trials were conducted for 218 days to track N uptake in tall fescue to validate the model. Incubation results showed that creating two models, one for low SOM content ($R^2=0.47$) and one for high ($R^2=0.89$), increased predictive power. Predictors included moisture, bulk density, texture, total carbon (C) and N, particulate organic matter C, and general enzyme activity among others. Temperature response was similar for all soils. Greenhouse results revealed that models over-predicted N_{min} for most soils, perhaps due to moisture dynamics, depleted N pools, or interactions with plants. Regardless, results suggest that these models can be useful tools for growers in California.

7

How does rate and timing of N fertilizer management affect yield and quality in California malting barley?

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Unlike other grains that are managed for high protein, malting barley is required to have a fixed protein concentration range (i.e. approximately 9% – 10.5%) making nitrogen management especially dynamic and unpredictable. This study seeks to improve quality and yield outcomes for malting barley in California by optimizing the timing and rate of nitrogen fertilizer management. We planted multi-site small plot trials with multiple varieties of malting barley treated with nitrogen amounts that ranged from 0 lb N/ac to 140 lb N/ac with different ratios between pre-plant and tillering. We analyzed yield and grain quality data (eg. protein, protein modification, beta-glucan) in linear and non-linear models to quantify the effects of N fertilizer rates, fertilizer timing and trial location. At the site in Davis, CA where there was a significant yield response in the 2016-17 season, increasing the rate of nitrogen fertilizer from 0 lb N/ac to 80 lb N/ac increased yield by almost 2000 lb/ac and also increased protein from 9.4% to 10.4%. Increasing nitrogen rates above 80 lb N/ac did not significantly affect yield but continued to increase grain protein above the 10.5% recommended maximum. At the same site, treatments with 110 lb N/ac applied at tillering yielded an average of 785 lb/ac more than treatments with 110 lb N/ac split between a pre-plant and tillering application. More data is needed to fully understand these relationships including the interactions between variety, environmental factors and nitrogen management. Preliminary results indicate that after consideration of variety and location yield potential, increasing nitrogen rates and applying nitrogen at a later growth-stage will significantly increase both yield and protein.

8

The agronomic and economic potential for wheat to be harvested as a dual-purpose crop in California

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Previous studies in the Southern Great Plains have shown the agronomic possibility and economic importance of wheat grown as a dual-purpose crop for forage and grain. This study seeks to understand the implications of growing wheat in California as a dual- purpose crop in high and low productivity systems. The dual-purpose system could be beneficial in years where water is not guaranteed, as wheat can be harvested for an early season forage with the potential for regrowth, ensuring economic returns. To assess agronomic and economic feasibility, three treatments were compared, 1) wheat as a dual-purpose crop, 2) wheat as a forage crop, and 3) wheat as a grain crop. The dual- purpose wheat was harvested as green chop during the boot stage and subsequently harvested for grain, the forage-only crop was harvested during the soft dough stage, and the grain-only crop was harvested at maturity. Biomass yield, phenological stage, regrowth, and grain yield data were collected on two varieties, Blanca Grande 515 and Cal Rojo at the University of California, Davis during the 2016 -2017 growing season. Price scenarios were created using historical data on green chop, forage, and grain to calculate revenue. In the high productivity system, the dual-purpose revenue was significantly higher than the hay-only system in 2 of 28 price scenarios, and was not significantly higher than the grain-only revenue. In the low productivity system, in 12 of 28 price scenarios, the dual-purpose revenue was significantly higher than the hay revenue and grain revenue. These results suggest that the dual-purpose wheat system could be advantageous in the context of California for a wheat crop with low yield potential.

9

Deficit Irrigation Strategies and Alfalfa Variety Interactions Under Subsurface Drip Irrigation

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In California, periodic droughts and water shortages have strengthened the need for irrigation management strategies to avoid economic losses and reduce long-term impacts. Irrigation systems with greater application efficiency, such as subsurface drip irrigation (SDI) may prove to be useful tools in the practice of deficit irrigation when water uncertainties exist. The objective of this research was to determine the possible interaction between variety and deficit irrigation utilizing SDI techniques. Fifteen commercial or newly released alfalfa varieties were established in a Davis, CA field in 2014 in a split plot design with four replications using four different irrigation regimes utilizing SDI. Irrigation treatments were; 1) Full -100% of crop ET_c, 2) 75% of crop ET_c with an August cutoff, 3) 75% of seasonal ET_c, -fully irrigated to 50% of seasonal ET, then 1⁄2 of full irrigation for the remainder of the season, 4) 50% of ET_c –with a July cutoff. Data were collected over the three growing seasons of 2015 through 2017. Yields averaged 90% of fully-irrigated plots at 50% water application and cutbacks of 25% of seasonal water demand resulted in approximately 96% of the yields under full irrigation averaged over three years. Varieties differed significantly in yield potential ($P<0.05$), but there were no significant interactions between variety and irrigation strategies. Effect on stand persistence is not fully known, but is an important factor to consider when utilizing deficit irrigation strategies. Soil type and environment are likely to be important factors in determining deficit irrigation success. However, this data supports the concept of late-season deficit irrigation strategies as a key to adjusting alfalfa production techniques to water uncertainties in the future.

10

Use of EM-38 Soil Surveys in Forage Fields at a Saline Drainage Water Reuse Site to Calibrate a Hydro-salinity Model for Decision Support

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Soil salinity is a major factor affecting irrigated agriculture in the western San Joaquin Valley of California. Soil salinity is a spatially and temporally dynamic property, and thus, mapping at the field scale requires a rapid and reliable means of taking geospatial measurements. EM-38 soil salinity surveys were conducted at the SJRIP (San Joaquin River Improvement Project) facility managed by the Panoche Water District (Los Banos, California) where subsurface drainage water is re-used on forages such as 'Jose' tall wheatgrass (*Thinopyrum ponticum* var. 'Jose') and alfalfa (*Medicago sativa*) to reduce drainage discharge and salt loading into the San Joaquin River, and also provide drainage service to 100,000 acre Grasslands Drainage Area (GDA). Soil samples taken to a depth of 120 cm (4 ft.) in 30 cm (1 ft.) increments for calibration of EM-38 data, were analyzed for pH, EC_e, gravimetric water content and saturation percentage. Real-time irrigation water salinity data were also measured using EC sondes installed in each field. The average EC_e for spring and fall 2016 samples was 12.5 to 19.3 dS/m for tall wheatgrass (TWG) fields and 8.9 to 14.4 dS/m for alfalfa (ALF) fields. In 2017, the average ECe ranged from 14.4 to 18.6 ds/m and from 9.5 to 13.3 ds/m for TWG and ALF fields, respectively. GIS maps were developed depicting the spatial variability of salts in the fields. Data will be used to calibrate a computer model (CSUID) developed as a decision support tool to optimize soil leaching requirement guidelines for irrigation water of varying salinity levels, with the overall goal of improving the sustainability of forage production using saline waters in the SJRIP.

11

Development of Molecular test (Diagnostic PCR) for the identification of Lepidopteran pests in Almonds and Pistachios

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Almond and Pistachio industry contribute around $6.66 billion to California's farm exports. Such high valued crops are infested by many lepidopteran pests causing damage. All these pests cause severe damage during the early part of their life cycle. Therefore, there is a sense of urgency for the control of these pests. However, these lepidopteran pests look similar during their larval stages that causes damage to the crop making the species level identification difficult. Currently available sources of pest identification are costly and time consuming. Here arise a need for quick, cheap and accurate methods of pest identification at all the stages which, enabling growers to make control decisions. Here, we report the design of a multiple genetic tools to rapidly and inexpensively identify lepidopteran pests.

1.Diagnostic PCR is developed by amplifying barcode region of the insect using species specific primer pairs. PCR is successful when the primers exactly match the template sequence therefore it can be used as an identification tool by designing primers specific to a single species DNA sequence. Cytochrome Oxidase-1 (CO-1) is the barcode gene used in the test. For this work we will combine multiple species-specific primers to amplify multiple targets on the template within a single PCR making it is possible to rapidly differentiate multiple species in a single reaction.

2. A more recent technique, RT-PCR/q-PCR enables concurrent detection, quantification and potential identification of specific DNA sequences using fluorescent dye, that fluoresces when hybridized with complementary DNA.

3. LAMP is an isothermal nucleic acid amplification technique in which isothermal amplification is carried out at a constant temperature, and does not require a thermal cycler.

GRADUATE STUDENT POSTERS—Ph.D. candidates

1

Quantifying the Green Water Resource in California Irrigated Perennial Agriculture

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Green water, the soil stored water from rainfall potentially available to crops, has potential to reduce agricultural reliance on streamflow and pumped groundwater (*blue water)*. To quantify and characterize the *green water* resource in California's perennial irrigated agriculture, the FAO-56 dual crop coefficient modeling approach was used to simulate irrigation of major perennial crops in CA (alfalfa, almonds, grapes, pistachios, and walnuts) on a 30 m grid basis using daily, publicly available data from 2005-2016. In addition to considering effects of weather and soil variability, we tested different crop rooting depths (0.5-3.0 m) and crop water stress irrigation management thresholds (30-80% allowable depletion of total plant available water in the root zone) to explore how varying the size of the soil water reservoir affects the *green water* resource and, consequently, *blue water* demand. Across these scenarios, the 12 year, cumulative *green water* resource ranged from 16-31 million-acre feet (MAF) out of a 46 MAF precipitation input, which represents 7-19% of cumulative growing season ET. Assuming a 2 m rooting depth and 50% allowable depletion, 20% of the landscape with perennial crops can meet 20% or more of its crop water demand with *green water*. Surprisingly, by enlarging the soil reservoir, *blue water* demand was reduced substantially more than the increase in *green water* utilization. This is because larger soil water reservoirs allow for less frequent but deeper irrigations, which reduces the surface soil evaporative loss. Thus, managing for *green water* through practices such as delaying time-to-first irrigation and promotion of deep crop rooting, can reduce reliance on *blue water,* not only by decreasing deep percolation but also by reducing evaporation at the soil surface.

1

How do moisture patterns in subsurface drip irrigation impact soil health?

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Over the last decade, subsurface drip irrigation (SDI) has been widely adopted in processing tomato systems in California's Central Valley. In conventional systems, precise placement of water and fertilizer into the root zone has potential to increase tomato yields while also increasing efficiency of these resources. In organic systems, however, nutrient availability to the plants is largely reliant on mineralization of organic forms in compost and cover crop residues, a process driven by microbial activity. In SDI systems, only a portion of the soil is wetted while the majority of the soil volume remains dry during the growing season, including the surface soil where microbial biomass and activity is usually highest. We asked whether this prolonged lack of moisture could negatively impact microbial communities, limiting the release of nutrients and transformation of carbon (C). Our study explores how the soil moisture patterns created by SDI affect C and nitrogen (N) pools, soil aggregation, microbial biomass, and plant nutrient uptake. This experiment is being conducted at the Russell Ranch Sustainable Agriculture Facility in Davis, CA, and compares SDI and furrow irrigation in organically managed tomato systems, as well as SDI in conventionally managed tomatoes. Steeper moisture gradients and drier surface soils with SDI likely contributed to declines in microbial biomass C in parts of the bed. Additionally, SDI plots showed a trend towards poorer aggregation, though both organic treatments had more stable aggregates than the conventional treatment. Despite greater weed cover and lower irrigation water productivity, the organic furrow-irrigated plots out-yielded the organic SDI plots, and greater vegetative biomass in organic SDI may indicate a mistiming of nutrient availability.

3

Quantifying water productivity, forage quality and yield of *Medicago sativa* L. (alfalfa) under subsurface drip irrigation (SDI)

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There is a critical need for improvement in irrigation strategies for sustainable forage production in California given the challenges of periodic droughts and climate change. Subsurface drip irrigation (SDI) system may use water more efficiently due to more timely applications and better distribution uniformity. This study was designed to understand the potential of SDI in alfalfa for increasing water productivity, forage quality and yield of alfalfa under varying water deficits. The study was conducted at Parlier, CA on sandy loam soil with five treatments: T_1 (Check Flood Full irrigation, 100% of ET), T_2 (SDI-50% deficit, midseason cutoff-July), T_3 (SDI-25% deficit, cutoff mid-August), T_4 (SDI-25% deficit, with full irrigation to July, followed by applying 50% of ET), T_5 (SDI Full irrigation to 100% of ET), using a randomized complete block design with four replications. Daily crop evapotranspiration (ET_c) requirements were calculated using the reference ET_o from (CIMIS) data for Parlier with irrigations following ET_c. The first year (2017) results of this study revealed significant differences among the treatments with an increase of 9% in yield with SDI-Full compared to check flood irrigation, and a 12.4% increase in water productivity. Deficit treatments resulted in significant reductions in yield, but higher water productivities. The highest was in T_2 (2.2 t/acre-foot) and lowest (1.9 t/acre-foot) was found in check flood. Water deficit had minimal effects on the forage quality in all treatments. SDI system has a potential to increase alfalfa water productivity due to its ability to more closely match ET_c, and could be valuable during deficit irrigations due to the ability to apply small amounts of water to keep the crop from damage during droughts.

4

Observed and Projected Climate Change Impacts on Productivity and Efficiency of Wheat Across California

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California is a major food producer in the United states, accounting for 1 in 4 items on the table of every American household. California is also a drought prone region under increasing climatic variability. Thus, developing a quantitative understanding of agricultural resilience to climate change in California's semi-arid landscapes is critical to ensuring food security in the future. In this study we quantify long-term changes in yield and resource-use efficiency in wheat across California since 1981.We use statistical models to elucidate thresholds for crop production, quantifying regional shifts in agricultural sustainability by pairing time series analysis with geospatial spatial data. Our approach consists of identifying environmental, edaphic, genetic, and management drivers that have affected water-use efficiency (WUE) and nitrogen-use efficiency (NUE) to understand how resource use and climate interact to control yield production and stability under changing climates. While climate does impact yield and resource efficiency, other factors such as pest, fertilizer, and irrigation management are just as important, and can override the role of local climate. We identify the varied importance of these drivers in regions of California with distinct production trajectories (i.e. areas that have increased, decreased or remained the same over the past 35 years). Despite these other factors, it is clear that climate does play a role, even in systems, which are closely managed for water stress. As a result, we are able to use downscaled global climate models to predict the impact of future climate conditions on productivity in wheat over the next century

5

EFFICACY OF NEW NON-FUMIGANT NEMATICIDES AGAINST ROOT-KNOT NEMATODES IN TOMATO GREENHOUSE TRIALS

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Plant-parasitic nematodes are one of the main research targets for pest and disease management in tomato (*Solanum lycopersicum* L.) production. Worldwide losses caused by root-knot nematodes reach 27%. Among the most important species is *Meloidogyne incognita*, because it is an aggressive species with a widespread distribution throughout the world. New non-fumigant nematicides Nimitz 480 EC (a.i. fluensulfone), Velum One (a.i. fluopyram) and Salibro (a.i. fluazaindolizine) were tested in greenhouse tomato trials with the aim of evaluating their effects on the severity of root damage and nematode reproduction. Four-week-old tomato seedlings (cv. Red Gnome) were planted into 2500 cm^3 fiber pots infested with 200 eggs of *M. incognita*/100 cm^3 sandy soil. The pots were drenched to water-holding capacity with water suspension of the test products. The rates simulated field application recommendations. The non-treated control received water only. The pots were arranged in a randomized complete block design with 5 replications. They were incubated in a greenhouse at 25˚C and ambient light for 60 days. The trial was repeated once with similar results and combined for statistical analysis (ANOVA, LSD test at P=0.05). All nematicide treatments reduced the root gall index, the number of *M. incognita* egg masses, eggs/g root and the nematode reproduction factor when compared to the non-treated control. The results did not differ among the product treatments. The new non-fumigant nematicides are attractive alternatives to current nematicides due to their low toxicity to non-target organisms and the environment. Based on this study, they showed excellent potential for the control of root-knot nematodes in tomato production

6

Managed Groundwater Recharge: Hydrologic Regime Change and Nitrogen Dynamics

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California has recently experienced a historically unprecedented four-year drought. In response to the past and in anticipation of future drought, farmers, out of necessity, have increasingly turned to groundwater to offset surface water reductions and meet their irrigation needs. Climate change forecasts predict increased precipitation variance with expected increases in flood event frequency, as well as drought events. To take advantage of future flood events, agricultural groundwater recharge presents an innovative climate change adaptation tool for farmers to secure a long-term water supply and buffer against surface water allotment reductions during future droughts, while mitigating potential damage from flood events downstream of farms. Of particular concern is the potential for groundwater recharge to exacerbate nitrate (NO_3^-) contamination of already at risk aquifers. We took cores down to 9 meters (30 feet) in grape, almond, and tomato cropping systems and analyzed them for NO_3^-, dissolved organic carbon, iron (II and III), texture, and moisture. Seventy eight percent of nitrate values were above the EPA drinking water quality standard of 10ppm. Grape cropping systems had the lowest mean NO_3^- concentrations, with no difference between almonds and tomatoes suggesting that grapes may be a preferable crop to conduct groundwater banking. However this relationship changed below four meters possibly indicating differences in water movement under differing irrigation management or higher rates of NO_3^- attenuation under differing cropping management. Evidence for denitrification is being examined with preliminary results showing that iron (II) is significantly negatively correlated to NO_3^- suggesting the reduction of NO_3^- by iron (II). Denitrification potential assays and QPCR will be conducted to better understand the potential for denitrification in the deep vadose zone.

PROFESSIONAL (NON-STUDENT) POSTERS

1

Managing Canopy Size and Spacing in High Density Planting of 'Hass' and 'Lamb Hass' Avocados (*Persea americana*) in Southern California

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California produces about 90% of the nation's avocado (*Persea americana*) crop. Currently the cost of water in San Diego County is approximately $1,600/ac ft. To adapt, growers need to increase yield per acre using the same amount of water or less. As an alternative to planting at the traditional spacing of 20' x 20,' trees for this project were planted at a high density spacing of 10' x 10'. We planted nine 9-tree units in blocks of 72 'Hass' and 72 'Lamb Hass' avocados, all on 'Dusa' rootstalks, in August 2012. The trial consists of a comparison of two different methods of pruning (traditional all sides pruned and topped at 8 ft) and alternate side pruning (southwest side pruned every other year with the northeast side pruned in alternate years). We are comparing 5 alternate side pruned units to 4 traditional pruned units within each variety. Yield was collected on the third, fourth and fifth years after planting for 'Hass" and on the third and fourth years for 'Lamb Hass'. Results thus far have indicated no significant difference in yield between the two pruning styles, but taken as a whole the yields in the Hass block have been much higher than the county average yields for mature trees of 6,000-7,000 lbs/acre. In our trial from years 2014-2017 yield/ac in Hass has been 480 lb/ac, 13,246 lb/ac, 25,104 lb/ac and 5,641 respectively. The 2017 harvest was an off-year due to high temperatures in 2016. From years 2014-2016 yield/ac in Lamb Hass has been 975 lb/ac, 8,796 lb/ac and 15,243 lb/ac respectively. Pruning methods and costs still need to be further evaluated.

2

A comparative approach of evapotranspiration- and soil sensor-based technology to improve irrigation efficiency

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Efficient management of water resources is paramount to the sustainability of irrigated agriculture, particularly in regions such as California which are highly impacted by climate variability and diminished water supplies. One approach to improve irrigation efficiency is to implement irrigation scheduling practices that couple the use of sensor technology with accurate estimations of crop water requirements. Many sensors and data logging equipment are available to trigger irrigation applications based on measurements of soil water content or crop evapotranspiration (ET). To evaluate these options, we conducted field studies on various crops (lettuce, tomato, sorghum, corn) grown under different irrigation regimes (flood, drip) and irrigated following an ET- and a soil sensor-based scheduling approach. The study site, located at California State University, Fresno, was characterized by sandy loam soils. For the sensor-based approach, six capacitance-soil moisture devices installed at three locations and two depths (6'' and 12'') were used with a datalogger and a 24VAC solenoid valve. Irrigation scheduling was programmed using upper (field capacity) and lower thresholds (30% maximum allowable depletion) of soil available water. Irrigation applications were triggered when the average soil moisture values reached the lower threshold and ended after field capacity was attained. For the ET-based approach, an irrigation scheduling program was developed to: 1) poll daily ET data from the Madera CIMIS station (#188) using the CIMIS web Application Programming Interface (API) over radio and internet links, and 2) calculate daily irrigation applications. In addition, some fields were irrigated based on visual crop and soil observations and manually operating irrigation valves. Results show that both ET- and soil sensor-based technology can improve water use efficiency and help growers optimize their irrigation scheduling.

3

Quantifying the Benefits of On-farm Best Management Practices: Managing nitrate leaching using evapotranspiration-based irrigation scheduling

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Several low-cost best management practices (BMPs) and tools for irrigation and nutrient management are currently available to growers and irrigators. These tools include the CropManage irrigation and nutrient management software application, developed by the University of California Cooperative Extension (UCCE), the Satellite Irrigation Management Support (SIMS) system developed by NASA and CSU Monterey Bay to map crop coefficients and crop evapotranspiration (ETc), the soil nitrate quick test and the use of flow meters. Together, these tools can enhance the ability of growers and irrigators to use weather, satellite and soil nutrient data to manage irrigation and fertilizer to match crop requirements.

We present results from field trials using these tools and BMPs for irrigation and nutrient management for drip-irrigated lettuce and broccoli grown in the Salinas Valley, California. We applied two different irrigation treatments based on full replacement (100%) of crop evapotranspiration (ETc), and irrigation at 130% of ETc replacement. CropManage was used to calculate the 100% and 130% ETc replacement requirements prior to each irrigation event. We used a randomized block design with four replicates per treatment to quantify total applied irrigation, drainage, nitrate leaching and crop yield for each treatment.

For both lettuce and broccoli, we observed reductions in the amount of leached nitrogen in the 100% ET treatment relative to the 130% ET treatment, both as in terms of total nitrate loss and as a percent of nitrogen applied. The absolute reduction in leached nitrogen for lettuce was 32 lbs-N/acre (73%), and for broccoli it was 7 lbs-N/acre (18%). There were no significant differences in yield or quality for either crop, and commercial harvests for both met or exceeded industry averages.

4

The South San Joaquin Valley Management Practices Evaluation Program Management Online Support Tools

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The key to successful implementation of the MPEP is providing management practice information to growers and their advisors so that they can easily access and implement it. The SSJV MPEP launched ***agmpep.com*** in early 2017 and provides resources for growers and advisors looking for information about protective practices, nutrient management tools, learning opportunities, and more. **Developed Products:** *1) Nitrogen Management Calendar* – This calendar compiles nitrogen management outreach events where users can learn about relevant nitrogen management planning. *2) Irrigation Water Nitrogen Calculator* – Irrigation N is indistinguishable from fertilizer and native soil N. A careful accounting of applied N is needed for grower nitrogen management plans. When users enter irrigation water parameters (e.g., N concentrations and applied water depths), the tool produces an estimate of N (lbs N $acre^{-1}$) from up to two distinct irrigation water sources. *3) Nitrogen Removal Calculator* – Growers and advisors can estimate N removed (R) and the ratio of applied (A) to removed (R) N (A/R) in crops. *4) Evapotranspiration (ET) Variability Viewer (EVV)* – Fields variability can be hard to assess, yet understanding variability helps growers better manage water and nitrogen. The EVV displays field-by-field actual ET uniformity for an irrigated growing season (May through October, 2014). Users may visualize these data on field maps, frequency distributions, and distribution uniformity statistics. Users can view data from fields they manage to visualize field-level ET variability. Several of the tools offer offline versions for download, including tabular data entry for working with multiple fields.

5

Connection Between Nitrate in Root Zone and Groundwater as Affected by Crop and Soil Management

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High-frequency, low-rate (HFLR) irrigation systems (i.e., drip and microspray) are increasingly common in California. They are often cited as a means to increase both water and nitrogen use efficiencies (WUE, NUE). However, system operation strongly influences WUE and NUE, so the potential benefits of widespread HFLR infrastructure can only be realized if the systems are operated in modes that allow the achievement of these goals. **Objective:** Use actual evapotranspiration (ETa), soil, and plant information to assess N leaching and identify potential management (i.e. irrigation and fertigation) shifts that would improve WUE, NUE, and yield. **Methods:** Combining land-based and remote sensing data on soil and plant conditions with operational management records to determine N leaching, N and salt fate, and factors limiting productivity in almond and orange fields on a medium-sized farm on the Kings River Fan near Fresno, California. **Results:** Salt and N build-up occurred at the margin of almond but not citrus rooting zone, suggesting that orange root zone available water capacity exceeds available water. N accumulated beyond the almond root zone might be recovered by planting a deep rooted, salt-tolerant cover crop. More frequent irrigation will improve uniformity, production, and environmental performance in oranges. Grower needs to fertigate at the end of irrigation runs to maximize N residence time in the root zone and minimize N transport to root zone margins. Low ETa in almonds points to water stress. Implement pressure and flow measurement to provide better information on applied water rates, which are below design flow rates.

6

Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops

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Water quality regulations will require increasingly efficient N fertilizer management to minimize N surplus and leaching. Accurate estimation of N concentration in harvested crop materials is essential for estimating N surplus. Here, we report on factors affecting N content of peaches in the central valley of California. **Objectives:** Characterize N removal rates in California peaches over a range of growing conditions, update N-removal coefficients used for calculating N removal in California peaches, and determine procedures for N removal determination. **Methods:** Peaches collected throughout 2017 growing season, primarily near Sanger river bottom and Kerman from fields with similar management, growing early- through late-season harvested peaches. Analyses of sampled flesh and pits were conducted at the UC Davis Analytical Laboratory. **Results**: One representative subsample of 7 fruit is sufficient to characterize N-removal per field; additional samples may not provide additional precision. Pit N was greater where kernel and shell were analyzed separately rather than left whole ($p < 0.0001$), perhaps due to preferential subsampling of the shell over kernel tissue after grinding. However, pit N is a minor component to whole peach N. Peach flesh may be analyzed as a wet puree, and scrubbed pits dried whole, or after cracking to speed drying. As growing degree days increased, fruit dry matter % increased ($p < 0.006$, $R^2 = 0.75$) while N content in dry matter and fruit decreased ($p < 0.004$, $R^2 = 0.74$; $p < 0.007$, $R^2 = 0.73$). These results may be used to determine a general N-removal coefficient or to determining harvest-date specific N-removal rates.

7

Airjection® Irrigation Impact on Soil Nitrogen Cycle Gene Communities: Methodology and Preliminary Results

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Using a high efficiency venturi to inject air into water delivered through subsurface drip irrigation, commonly referred to as AirJection® Irrigation, has been shown to result in increased crop yields. Our previous studies have also indicated that the technology can positively affect photosynthetic activity, stomatal conductance and soil respiration rates. In this phase of the research, we are comparing the relative quantity of genes known to be involved in the Nitrogen (N) cycle for soils in vegetable fields subjected to AirJection® Irrigation with those that were not aerated. DNA was extracted from soil samples collected within the top 15 cm using a PowerSoil™ kit and gene quantification of the microbial populations was obtained via polymerase chain reaction. Nitrogen cycling genes were selected to describe the entire N cycle from nitrogen fixation (nifH) to nitrification (ammonia oxidation), and denitrification (Nitrate, nitrite and nitrous oxide reduction). Abundance of the tested genes was normalized to the abundance of the bacterial or archaeal indicator ribosomal genes (16S rDNA). Thus, results represent the possible intensity of the respective function among the bacterial or archaeal populations but not necessarily the absolute counts of each gene per unit soil mass or volume. Our preliminary findings for a Panoche clay soil collected from a commercial vegetable production site in Mendota, CA indicate that AirJection had a clear selective impact on the distribution of the tested genes among the soil microbial population. While AirJection did not impact N fixation or ammonia oxidation, it did significantly change the denitrification genes population in manner that can positively affect nitrogen use efficiency. Furthermore, with judicious water management within the root zone, AirJection Irrigation can favor the dominance of bacteria that enhance plant nitrate uptake with a potential reduction in nitrate leaching.

8

Winning the Battle Against Environmental Stress by Better Understanding Biostimulant Responses

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Biostimulants are increasingly being used by growers to manage environmental stress. Some examples of biostimulants include seaweeds, organic acids, plant based extracts, amino acids, fermentation products, algae, and reprocessed vegetative matter.

Holden Research and Consulting (HRC), an independent agricultural research firm in California, has conducted over 500 trials with biostimulants over the last ten years. HRC's findings indicate that they can be valuable tools in the management of problems caused by abiotic stress factors such as salt and heat.

HRC has closely studied and compiled data from various trials with three biostimulant products: the marine plant *Ascophyllum nodusum*, FB Sciences' Complex Polymeric Polyhydroxy Acids (CPPA), and California Safe Soils Harvest-to-Harvest (H2H - recycled food from supermarkets). These products have all demonstrated improved yields under high-induced salt conditions by an average of 28%, 96% and 112% respectively. A series of forty-three strawberry trials treated with biostimulants under good growing conditions resulted in 36% of these products improving yield by more than 10% prior to an environmental stress event. However, under heat stress brought on by a four day heat wave, 71% of these products showed better than 10% increase in yield after the heat event, indicating that optimum benefit may be seen from these products when utilized under stress conditions.

Although biostimulants are neither nutrients nor pesticides, they offer real value to the grower against environmental stress factors and are quickly becoming a valuable resource in the agricultural industry world-wide.

9

Understanding the Season Long Incidence of Pepper Weevil in the Santa Clara and San Benito Pepper Production Areas

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Pepper weevils are a serious threat to pepper production and can cause significant economic losses. This pest has been active in southern California for many years, and has recently been observed in pepper fields in the Central Coast, a region outside the pest's typical habitat. To understand the extent of the pest problem and its seasonal incidence, several pepper fields were monitored in the Santa Clara-San Benito production region from May-November in 2016 and 2017. Pheromone baited yellow sticky traps were installed in grower fields and were assessed on a weekly basis. Data analysis is on-going but preliminary results show the following: 1) the pest infestation was more intense in 2017 than in 2016. Total weevil counts for the season were 3,100 in 2017 and 1,106 in 2016. 2) Two peaks in pest levels were observed during the production season. One small peak at the beginning of the season in June and the second around September-October. The peak in June corresponds to the beginning of the pest infestation prior to any insecticidal application. During the spray period from June to August, weevil counts were low, around 1-2 per field. Starting in August (which overlaps with rollbacks in insecticidal application), fields became heavily infested until the end of October in 2016 and mid-November in 2017. The peak infestation levels of the season shifted from September in 2016 (330) to October in 2017 (463). From October onwards, fruit drop was observed in some infested fields. Upon dissection these fruits were found to be infested with various stages of pepper weevil. Further research is needed to better understand the seasonal incidence of the pest.

10

Using a Partial Budget Approach to Assess the Economic Value of Deficit Irrigated Navel Oranges

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Growing oranges under drought conditions is a challenging task that has influenced growers to consider the adoption of regulated deficit irrigation (RDI). In addition to assessing the impact of limiting water application during specific phenological stages on the yield and quality of the fruits, it is also critical to evaluate the economic feasibility of implementing RDI. This research was conducted at two locations in California using five irrigation regimes, during the months of July and August, to assess the effect of limited water application on the quality and economic yield of navel oranges. Partial budget modelling was used to assess the economic impact of reduced water application on the price of the oranges sold in the U.S. and exported to Japan. In this approach, only resources that are changed, such as reduced water application, assuming that the costs of all other are resources are unchanged, are evaluated for its potential to vary the farm income. Partial budgets were based on changes in the following: increase in income, reduction or elimination of costs, increase in costs, and reduction or elimination of income. The net impact of the effects was calculated as the positive financial changes minus the negative financial changes. At both locations there was a significant difference in fruit Brix index and yield at lower RDI treatments compared to fruit receiving higher doses of water. The implementation of RDI in navel oranges can increase crop quality, yet severe RDI levels can decrease yield. Generally, the price of "free-watered" citrus in the U.S. was lower than citrus in the Japanese market. More importantly, the economic analysis adopted in this study showed the Japanese market was an incentive to: (1) manage water to benefit from that niche market, and (2) produce fruits of lower weight that would ultimately be compensated through higher prices.

11

Costs and Returns Studies of Production on Agricultural Crops

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Cost and return studies became a mainstay of UC Cooperative Extension outreach starting in the 1930s. The studies provide information on the expected costs, yields, revenue, and net returns on a per acre basis for a specific commodity and a given county or region of California based on a specific hypothetical, well-managed farm enterprise. A production cost study begins with a meeting among UCCE farm advisors, farmers and a research staff person from the Agricultural Issues Center to gather information on production operations of the crop. This information is then entered into a stand-alone computer program which calculates costs and returns based on standardized economic and engineering formulas. The draft of the study is sent out to contributing advisors and selected growers for review. The finished study is posted on the department website with full access to the public. Over 3,500 cost studies are maintained and are archived on the cost studies website, which are free to download. The calendar year for 2016 shown that over 1.3 million studies were downloaded from the website.

12

Processing Sustainable Practices: 24 Years of Tomato Yields under Conventional, Organic, and Winter Cover Crop Management Systems

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For the past 24 years, management practices of interest due to their soil quality benefits, including winter cover cropping (WCC) and compost inputs, have been investigated in a long-term cropping systems trial at Russell Ranch, a UC-Davis research facility in the Sacramento Valley. Processing tomato yields were compared in three cropping systems employing two-year rotations: 1) conventional maize–tomato receiving chemical fertilizer (CONV), 2) conventional WCC/maize–WCC/tomato receiving chemical fertilizer (MIXED), and 3) organic WCC/maize–WCC/tomato receiving composted poultry manure (ORG). Additionally, in 2014–2017, reduced rates of nitrogen (N) fertilizer were applied to strips within plots in the MIXED system, to compare tomato yields after WCC under reduced N rates compared to the standard N rate and following winter fallow (CONV). Across 24 production years, tomato yields were similar among the CONV, MIXED, and ORG systems and increased over time, but yields increased at a greater rate (2.8 t ha^{-1} yr^{-1}) in the CONV and MIXED systems than in the ORG system (1.6 t ha^{-1} yr^{-1}). Tomato yield variability was greatest in the MIXED system, followed by the CONV system, and was lowest in the ORG system, relative to 24-year system averages. Lower tomato yields were observed following WCC with reduced N fertilizer rates of 30–100 kg N ha^{-1}, but yields were similar at reduced rates of 120–160 kg N ha^{-1} following WCC compared to yields from the MIXED and CONV standard rate (200 kg N ha^{-1}) treatments. Twenty-four years of yield data suggest that WCC do not reduce tomato yields but likely increase yield variability in the long term in conventional systems, and that WCC may provide residual N credits of 40 to 80 kg ha^{-1}.

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Chapter web site: ***http://calasa.ucdavis.edu***

California Chapter – American Society of Agronomy

2017 Plant and Soil Conference Evaluation

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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. Which session(s) did you find to be particularly informative/of great interest?

____

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

a.____

b.____

4. **Please suggest Chapter members who would be an asset as Board members.**

   a.____

   b.____

5. **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.**

   ____

   ____

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

   ____ Fresno ____ Visalia ____ Modesto ____ Sacramento ____ Bakersfield

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8. **Additional comments:**____

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