American Society of Agronomy
California Chapter

Co-Sponsored by the California Plant Health Association

2017 Conference Proceedings

California Plant and Soil Conference

Agricultural Information Overload
–separating fact from fiction

January 31- February 1, 2017

Double Tree Hotel & Fresno Convention Center
2233 Ventura St. Fresno, CA 93721

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

9:15 a.m **General Session Introduction:** Chapter President, Dr. Robert Hutmacher, University of California, Davis.

9:30 – 10:30 **Keynote Speaker–Dr. Ken Cassman,** Professor Emeritus, University of Nebraska, Lincoln. Former Head of the Agronomy, Plant Physiology and Agroecology Division of the International Rice Research Institute (IRRI) in the Phillipines.
""Big Data Versus Big Relevant Data: The perfect as enemy of the good"

DAY 1 (Tuesday, Jan. 31st) CONCURRENT SESSIONS: 10:40 a.m. – 12:15 p.m.

Session 1 – Pest/Weed Management Chairs: Margaret Ellis & Rachel Naegele			**Session 2 – Nutrient Management: Responsibilities and Liability.** Chairs: Karen Lowell & Ann Collins Burkholder	
10:40	Introductory remarks		10:40	Introductory remarks
10:45	**Steven Fennimore**, UCCE Weed specialist, UC Davis. *New automated technology has the potential to improve weed control systems in vegetable crops*		10:45	**Tess Dunham, Esq.,** Attorney, Somach, Simmons & Dunn Attorneys at Law, Sacramento, CA *Understanding Grower Liability in Nutrient Management Planning*
11:10	**Tim Miles**, Professor, CSU Monterey Bay. *Detection of Erysiphe necator fungicide resistant alleles in environmental samples*		11:10	**John Dickey,** Soil Scientist/Agronomist, PlanTierra LCC, Davis, CA *Case Study: Managing Liability Risks as a Soil Scientist*
11:35	**Pete Goodell**, IPM Extension Coordinator, UCCE *IPM: It's Time to Revisit a Familiar Concept*		11:35	**Harrison W. Scheider,** V.P. & Environmental Ins Broker, American Risk Management Resources Network, LLC *Environmental Liabilities and Risk Transfer Solutions for Certified Crop Advisors*
12-12:15	**Q&A/ Discussion (all speakers)**		12-12:15	**Q&A/ Discussion (all speakers)**

LUNCH- DAY 1 12:15 – 1:25 p.m.

DAY 1 (Jan. 31st) CONCURRENT SESSIONS: 1:30 – 3:00 p.m.

Session 3 – Nutrient Management Chairs: Sharon Benes & Hossein Zakeri			**Session 4 – Complex Issues in Agriculture** Chairs: Dan Munk, Stan Grant, Bob Hutmacher	
1:30	Introductory remarks		1:30	Introductory remarks
1:35	**Jeff Schoenau,** *Professor and Chair, Ministry of Agriculture Strategic Research*- Univ. Saskatchewan – Canada. *Availability of Nutrients in Manures*		1:35	**Cliff Ohmart,** Senior Scientist, Sure Harvest. *Comparing sustainable farming to conventional, organic and biodynamic farming*
2:00	**Richard Smith**, UCCE Monterey Co. *Nitrogen Technologies for Improving N use efficiency in leafy green vegetable production*		2:00	**Tom Willey,** *TD Willey Farms- Madera, CA. Resource sustainability in organic agriculture: Public understanding*
2:25	**Bob Beede**, formerly UCCE King's Co. *Zinc nutrition in perennial plants: a historical and current research review*		2:25	**Carl Winter**, *UCCE Food Toxicology Specialist*, UCD. Pesticide residue issues in California: Is our food safe?
2:50-3:00	**Q&A/ Discussion (all speakers)**		2:50- 3:00	**Q&A/ Discussion (all speakers)**

BREAK 3:00 – 3:20 p.m.

DAY 1 (Jan. 31st) CONCURRENT SESSIONS: 3:25 – 5:00 p.m.

Session 5 – Agricultural Water Management Chairs: Robert Hutmacher & Dan Munk			**Session 6 – Soil Biology: Understanding Management Options and Potential Benefits** Chairs: Karen Lowell & Margaret Ellis	
3:25	Introductory remarks		3:25	Introductory remarks
3:30	**Helen Dahlke**, UC Davis. Sustainable groundwater management: on-farm vs. dedicated storage issues		3:30	**Eric B. Brennan,** Research Horticulturalist, Organic Crop Production, USDA-ARS, Salinas, CA. *Soil Health Lessons from Long-term, Organic Vegetable Research*
4:10	**Joel Kimmelshue,** Land IQ *Intentional Agricultural Recharge Suitability*		3:55	**Daniel Kluepfel,** Research Leader, USDA-ARS Crops Pathology and Genetics Research Unit, Davis, CA. *Impact of Biological Amendments on Agrobacterium tumefaciens survival in soil*
			4:20	**Margaret Shake Lloyd**, Small Farms Advisor, UCCE, Woodland, CA *Evaluation of Four Composts on Plant Productivity and Soil Characteristics*
4:45-5:00	**Q.A./ Discussion (all speakers)**		4:45-5:00	**Q.A./ Discussion (all speakers)**

EVENING SOCIAL – POSTER SESSION, WINE AND CHEESE RECEPTION, ETC. (5:00 pm, Location TBD)

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DAY 2 (Wed. Feb. 1st) CONCURRENT SESSIONS: 8:30 – 10:00 a.m.

Session 7 –Measuring and managing variability Chairs: Andre Biscaro & Stan Grant			**Session 8 – Water Sustainability** Chairs: Sharon Benes, Robert Hutmacher, Dan Munk	
8:30	Introductory remarks		8:30	Introductory remarks
8:35	**Patrick Brown** – UC Davis, Dept. Plant Science. *Precision Nutrient Management in California Orchards*		8:35	**Arthur Hinojosa**, CA Department of Water Resources. *SGMA implementation and regional water management/sustainability*
9:00	**Brent Sams -** E&J Gallo Winery. *Precision Viticulture Tools for Wine Grape Vineyard Management in California*		9:00	**Sarge Green**, California Water Institute (CWI), Fresno State *A SGMA* Implementation Update* **Sustainable Groundwater Management Act*
9:25	**Danny Royer -** Bowles Farming Co. *Creating Actionable Intelligence at Bowles Farming Co.*		9:25	**Parry Klassen**, Coalition for Urban & Environmental Stewardship (CURES) *CVSALTS: salt and nutrient management plans in coordination with SGMA and integrated water management*
9:50-10:00	**Q.A./ Discussion (all speakers)**		9:50-10:00	**Q.A./ Discussion (all speakers)**

BREAK: 10:00 – 10:20 a.m.

DAY 2 (Feb. 1st) CONCURRENT SESSIONS: 10:25 – 12:00 a.m.

Session 9 – Biostimulants Chairs: Eric Ellison & Dave Holden **2 speakers*			**Session 10 – New Ways of Looking at Old Problems: Innovations in agronomic analysis and research.** Chair: Mark Lundy	
10:25	Introductory remarks		10:25	Introductory remarks
10:30	**Patrick Brown**, Professor, University of California, Davis. *Overview of Biostimulants for Agriculture*		10:30	**Nicholas George**, UC Davis, Dept. of Plant Sciences. *Unlocking Information from Multi-environment Variety Trials via Principle Component Analysis Tools*
			10:55	**Daniel Turkovich/Matt Meisner**, Farmers Business Network *Bringing the Power of Big Data to Agriculture*
11:10	**Joshua I. Armstrong**, Ph.D. VP Biologicals R&D Mendel Biological Solutions, LLC *Biostimulant Discovery and Development Using Plant Gene Regulatory Networks*		11:20	**Tom Shapland**, Tule Technologies *ET-based Site-specific Moisture Release Curves for Forecasting Both Plant Water Stress and Plant Response to Irrigation Events*
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.

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GRADUATE STUDENT POSTERS—M.S. candidates

GRADUATE STUDENT POSTERS—Ph.D. candidates

PROFESSIONAL (NON-STUDENT) POSTERS

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Board Meeting Agenda
California Chapter of the American Society of Agronomy (ASA)
February 3, 2016
Wyndham Hotel and Conference Center
Visalia, CA
12:00 PM – 1:45 PM

1. **Call to Order: Richard Smith**, President, California Chapter ASA.
    a. Welcomed attendees to the 45th annual Business (Richard)
    b. Award meeting of the California Chapter ASA. 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 proceedings. Proceedings available online on the Chapter website (including additions for late posters abstracts).
    c. The conference is being conducted in cooperation with the California Certified Crop Advisors (CCA).
    d. Provide the committee with feedback on the evaluation forms (conference, arrangements, potential future Board members, potential future Honorees)
    e. Acknowledgements (ask to stand to be acknowledged):
        i. Students poster presenters and scholarship winners
        ii. Students who assisted with registration and assembling poster boards
    f. Thank yous:
        i. Acknowledged the many sponsors listed in the Proceedings for sponsoring the session breaks and evening wine/cheese social during the poster session (Dellavalle Labs, Denele Analytical Inc, Innovative Ag Services, LLC, Prime Dirt, S&W Seed Company, and Valley Tech Analytical Laboratory Services)
        ii. Acknowledgement was given to Western Plant Health Association for their student essay scholarship fund.
        iii. Acknowledged that CA ASA is non-profit academic organization and the meeting attendee registration fees help pay for conference costs.
    g. Introduced the Executive Committee and Governing Board and thanked members for their hard work for preparing this year's ASA Plant and Soil Conference. Board member positions are volunteered. He recognized the members plus student help particularly from CSU Fresno for help with registration.
        i. Past President, Steve Grattan (Honorees)
        ii. 1^{st} VP, Robert Hutmacher (General Program and Proceedings)
        iii. 2^{nd} VP, Sharon Benes (Conference site arrangements and advertisement)
        iv. Secretary and Treasurer, Dan Munk
        v. Governing Board
    h. Past Presidents and asked that they stand and be acknowledged.

2. **Business meeting minutes from the 2015 ASA Plant and Soil Conference** (Richard)
    a. Indicated that the minutes of the Feb. 5, 2015 conference was on page 4 of the proceedings
    b. Motion to approve the minutes was given (xxx) and seconded (xxx). Minutes for the 2015 business meeting passed as presented.

3. **Treasurer's Report** (Dan Munk)
    a. Dan Munk present Treasurer's report for the 2015 meeting and activities.
    b. Approval of Treasurer's report was moved (xxx) and seconded (xxx).
    c. Thanks were given to Kay Hutmacherand the following students from CSU Fresno for assistance in running registration both days at the meeting

4. **Nomination and Election of persons to serve on Governing Board** (Richard Smith)
    a. Brief overview of the Governing Board structure was provided: 9 regular Board members serving 3-year terms plus a 5 member Executive Board. According to by-laws, members on the Board represent diverse disciplines and represent academia, agencies and industry.
    b. Acknowledge: past President (Steve Grattan) and Board members completing their term of service: Karen Lowell, Mark Sisterson, Scott Stoddard
        i. Thank for their dedication and hard work.
    c. Current Board 2016 Board
        i. Bob Hutmacher - as President
        ii. Sharon Benes – as 1st VP
        iii. Dan Munk – as 2nd VP
        iv. Karen Lowell - as incoming Secretary/Treasurer
        v. Serving 2-year terms
            1. Andre Biscaro
            2. Margaret Ellis
            3. Dave Holden
        vi. Serving 1 year remaining term
            1. Eric Ellison
            2. Anne Collins Burkholder
            3. Hossein Zakeri
    d. Nominations opened for the election of persons to serve on the 2015-2016 Governing Board.
        i. Rachel Naegele,USDA Parlier
        ii. Stan Grant, Private Consultant
        iii. Mark Lundy, Small Grain Specialist, UCD - UCCE
        iv. Motion was made, seconded and passed to approve new members

5. **Presentation of awards to 2016 honorees** (Steve Grattan)
    Presentation of Plaques:
        i. Joe Fabry: presenter Bruce Roberts;
        ii. Larry Schwankl: presenter Terry Pritchard;
        iii. Scott Johnson: presenter Kevin Day.

6. **Student Scholarship Award (WPHA)**
    a. Karen Lowell (Chair of student scholarship committee).
        i. Karen acknowledge other committee members (Dan Munk, Eric Ellison) as well as the support from our sponsor (Western Plant Health Assoc).
        ii. Discussed the criteria used to judge the students; applicants were asked to provide 2 letters of recommendation plus a description of work aspirations.
        iii. Introduce: Director of Programs, Kayla Gangl from the Western Plant Health Association
    b. Winning essays announced by Karen and Kayla and presentation of the awards. The scholarship funds are provided by the Western Plant Health Association ($1,500)
        i. Alex Burkdoll Aitelli, California Polytechnic State University, San Luis Obispo
        ii. May Nhia Yang, California State University, Fresno

7. **Student Poster Awards**
    a. Scott Stoddard: Introduce the committee: Anne Collins, chair, Eric Ellison and Andre Biscaro. Thank the student volunteers for putting up the poster boards. Awards were made to graduate and undergraduate students.

8. **Old business and New business**
   None was introduced.

9. Reminder to fill out conference evaluation forms.

10. President passed the gavel (made special for the ASA California Chapter in 1978) over to Bob Hutmacher, the new incoming President.

11. Newly elected President Hutmacher present an award to former President Smith for his years of service on the Executive Board.

12. Thanked the audience for attendance and adjourned the business meeting at 1:45 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		James D. Oster
1976	Malcom H. McVickar		Audy Bell	2008	V.T. Walhood
	Perry R. Stout	1997	Jolly Batcheller		Vern Marble
1977	Henry A. Jones		Hubert B. Cooper, Jr.		Catherine M. Grieve
1978	Warren E. Schoonover		Joseph Smith	2009	Dennis Westcot
1979	R. Earl Storie	1998	Bill Isom		Roland Meyer
1980	Bertil A. Krantz		George Johannessen		Nat Dellavalle
1981	R.L. "Lucky" Luckhardt	1999	Bill Fisher	2010	L. Peter Christensen
1982	R. Merton Love		Bob Ball		D. William Rains
1983	Paul F. Knowles		Owen Rice	2011	Blaine Hanson
	Iver Johnson	2000	Don Grimes		Gene Maas
1984	Hans Jenny		Claude Phene		Michael Singer
	George R. Hawkes		A.E. "Al" Ludwick	2012	Bob Matchett
1985	Albert Ulrich	2001	Cal Qualset		Don May
1986	Robert M. Hagan		James R. Rhoades		Terry Prichard
1987	Oscar A. Lorenz	2002	Emmanuel Epstein	2013	Harry Cline
1988	Duane S. Mikkelsen		Vince Petrucci		Clyde Irion
1989	Donald Smith		Ken Tanji		Charles Krauter
	F. Jack Hills	2003	Vashek Cervinka	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 Brase
1994	George V. Ferry		Joseph B. Summers		Kenneth Cassman
	John H. Turner				William Peacock
	James T. Thorup				Oliberio Cantu

American Society of Agronomy

California Chapter

2017

Honorees

Ronald J. Brase

Kenneth G. Cassman

William L. Peacock

Oliberio Cantu—*in memory*

Ronald J. Brase
President, California AgQuest Consulting, Inc

Listening to many of the bios of honorees over the years, very few started and completed their careers on the same property. Most careers wove around the country before settling in California. Ron Brase's is somewhat of an exception. Growing up on a raisin farm near Rolinda, CA and working in his father's automotive shop, Ron learned an appreciation for both farming and technology.

Following his love for the latter, Ron received a Bachelor of Science degree in Mechanical Engineering at CSU, Fresno in 1966. After graduating, Ron worked as a supervisor of information systems for General Electric Co. in Schenectady, New York. There he developed development data base management systems, supervised and trained technicians and other end users. He also continued his post-graduate studies in Industrial Administration at Union College, New York.

Wanting to raise their children among family and on the farm, in 1976, Ron and his wife Sue returned to Fresno County, where he took a positon as a senior water management specialist with Harza Ag Services. There he provided irrigation scheduling and fertility management services for commercial crops. Always seeking to improve his understanding of how things work, Ron took Ag production courses at CSU Fresno to gain the fundamentals of soil-plant-water relationships. Using this information and the practical experience running the small family farm, he became known as a problem solver and was asked to train and supervise others.

In 1979, Ron teamed up with an old friend to start Crop Care Services, Inc., a company that would focus on plant nutrition and irrigation consulting. Crop Care Services, Inc. grew in consulting and support staff that serviced the San Joaquin Valley, Napa & Sonoma Valleys, and the Central Coast. In the mid 90's, Ron branched on his own to start California AgQuest Consulting. There, he emphasized addressing the most limiting factor and to 'treat the problem, not the symptom'. To do so, Ron consulted extensively with UC Cooperative Extension and USDA-ARS researchers and facilitated on-site grower trials.

Seeing technology as a means to improve the quality of services and efficiency, Ron was an early adopter of many technologies. Over the years, Ron incorporated into his company's services numerous soil moisture monitoring technologies (from gypsum blocks and neutron probes to the latest capacitance sensors) and crop sensing (weather stations, infrared thermometers, pressure chambers, aerial & satellite imagery). As an engineer and wanting to improve irrigation application efficiency, Ron was a strong proponent of micro-irrigation in the SJV, even installing subsurface drip and fertilizer metering in his own vineyard. Problem investigation and cropland development projects became a significant part of Ron's work. Using basic observations from soil coring/backhoe pits with lab analyses and a combination of technologies, Ron has helped growers solve or avoid agronomic problems on tens of thousands of acres, or more, across the state.

Believing that crop consultants are key to the sustainability of agriculture in California, Ron is a strong advocate for the Certified Crop Advisor program and has always been willing to share his knowledge and passion for irrigation and fertility management. Ron has trained and/or mentored numerous agronomists, many of which are members of this Plant & Soil Conference community, and supported those who worked for him to seek their own path. Ron has organized grower workshops and has written numerous articles for publications, such as, Raisin Bargaining Association Newsletter, Fruit Growers-Vine lines, American Vineyard, Growing Produce, and he even helped develop and produce radio spots. He has served in leadership on several non-profit Ag organizations, including SJV Wine Growers Association, SJV Viticulture Technical Group, and the CA chapter of the ASA (Plant and Soil Conference) where he served as President in 2004.

Still living on the family farm, Ron continues to promote agriculture to all who will hear, using science and a friendly can-do attitude. In total, Ron is a ‘champion of a fellow’.

Kenneth G. Cassman
Emeritus Professor of Agronomy, University of Nebraska

A California native, Ken Cassman was born and raised in Los Angeles. His introduction to agriculture came in the early 1970's when he started a half-acre organic vegetable garden in Solana Beach while an undergraduate at UC San Diego (UCSD) in La Jolla. He also helped establish the first organic food store in San Diego County, called the Peoples' Food Coop. An emerging interest in food production led him to complete a B.S. in Biology from UCSD and pursue his M.S. and Ph.D. at the University of Hawaii on phosphate nutrition of legumes. Ken returned to CA where he completed one year of post-doctoral research with Prof. Don Munns in the Dept. of Land, Air and Water Resources at UC Davis, working on legume nitrogen fixation. After this postdoctoral appointment, Ken turned his attention to international agriculture and over the next four years worked on improving rice management practices in Brazil and solving agronomic challenges in Egypt's Nile Valley.

Following this international sojourn, Ken joined the faculty of the Agronomy & Range Science Dept. at UC Davis. During the next seven years, he taught a core course in the International Agricultural Development M.S. curriculum and directed graduate students conducting research on the state's important field crops. Ken's leadership and bold scientific approach exploring agronomic constraints on optimum productivity led to redefining and improving major production practices used on cotton and wheat. He also was instrumental in developing the Long-Term Research on Agricultural Systems (LTRAS) facility at UC Davis.

After his stint at UC Davis, he served as Head of the Agronomy, Plant Physiology, and Agroecology Division of the International Rice Research Institute (IRRI) in the Philippines. Under his leadership, a team of international scientists identified yield constraints slowing the rate of yield advancement in several Asian countries. Identification of "yield ceilings" and "yield plateaus" were key elements of this work that helped explain the observed yield stagnation. From the Philippines, Ken returned to the US to serve as Head of the Dept. of Agronomy at the University of Nebraska. After eight years as Department Head, he returned to full-time research and extension and over the next 12 years held both the Daugherty and Heuermann Professorships in Agronomy, served as Director of the Nebraska Center for Energy Sciences Research, and chaired the Independent Science and Partnership Council for the Consultative Group for International Agriculture Research. In the last five years, Ken has focused attention on "yield gap analysis" as a tool for evaluating untapped crop production potential across spatial scales, from a single field to national and global levels. Recently Ken was awarded the Bertebos Prize from the Swedish Royal Academy of Agriculture and Forestry for his work on ecological intensification of crop production as the means to meet global food demand while also protecting the environment and conserving natural resources. Although officially retired from the University of Nebraska, Ken remains active publishing his research and serving as a consultant to commercial farming operations and other groups seeking to implement ecological intensification practices. He now lives in Oceanside, CA with his wife Susan.

In recognition of career accomplishments that have impacted international, national and California agriculture, the California Chapter of the American Society of Agronomy is proud to add Kenneth G. Cassman to the list of Honorees who have significantly influenced California agriculture.

William (Bill) L. Peacock
Extension Viticulture Farm Advisor Emeritus, University of California, Tulare County

Bill was raised in Tulare County California, in the Dinuba area, on a grape and deciduous fruit farm, and he is the fourth generation of his family involved in agriculture in Tulare County. Bill and his wife JoAnne also farm, and they began their career in 1979 with the purchase of 50 acres near Woodlake which they developed into a raisin vineyard. Today, they farm raisin grapes and citrus with additional properties located near Ivanhoe and Dinuba.

Bill was a UC Farm Advisor in Tulare County for 36 years retiring June 2008. He received both his Bachelor and Master's degrees from UC Davis. During his career, Bill demonstrated a passion for research, especially in areas of irrigation, nutrition, table grape trellis/canopy management systems, dried-on-vine raisin production systems, the use of plant growth regulators, and pest management.

Bill pioneered drip irrigation in the San Joaquin Valley, initiating research in 1972 that compared drip, flood, and sprinkler irrigation methods. He also pioneered drip irrigation scheduling using canopy development and historical evapotranspiration values. Irrigation research the past 15 years has been focused on deficit-irrigating table grapes in order to increase color and sugar maturity and improve fruit wood development.

In the 1980's, Bill began studies on the timing of nitrogen fertilizer using N^{15} depleted nitrogen which allowed tracing N fertilizer in the soil and plant tissue. The work showed that fall fertilization is by far the most efficient time to apply N which is taken up and stored in dormant tissue, and stored N is available to support early spring growth. Today, growers no longer apply nitrogen prior to budbreak which had been the common practice. In recent years, protocols for the application of nutrients through the drip system have been developed including nitrogen, potassium, zinc, boron, iron. Recent work with the foliar application of potassium applied late during ripening showed sugar and color maturity are advanced, and today many raisin and table grape growers use this technology to their advantage.

In the 1990's, Bill was a pioneer in the development of wide-open gable trellis designs and canopy management techniques including moveable foliage wires to divide canopies. Prior to his work, the standard table grape trellis was a simple 'T' using 3' to 4' cross arms. Today, table grape vineyards predominantly employ large open gables and canopy positioning wires. Towards the end of his UC career, Bill worked on dried-on-vine raisin production and developed a system allowing growers with a traditional trellis to dry raisins on the vine.

Bill has an excellent publication record, authoring 78 peer-reviewed research papers and abstracts; 60 Marketing Order research reports; 71 industry symposia proceedings; 260 UC and Tulare County publications. His work with nitrogen timing received the Best Paper award from the American Society for Enology and Viticulture in 1990. His educational efforts have been acknowledged with awards from the University of California Cooperative Extension and College of Sequoias.

Bill still has a passion for research and discovery. He continues to work with the industry on research and problem solving. Bill stated that “I am grateful to UC and the people of California who gave me opportunity to serve grape growers in Tulare County, and my wife and I are blessed that we were able to raise our family on the farm”.

Oliberio Cantu—*in memory*
Small Grains Plant Breeder, Resource Seeds, Inc.

Oliberio "Oly" Cantu began his plant breeding career breeding barley in California in 1969 and went on to play a major role breeding wheat and triticale in the state. He was born in 1947 in Laferia, Texas, to Maria and Seraphin Cantu, immigrant farm workers who moved the family from Texas to Montana in 1951 to work in the sugar beet fields there.

Oly attended Montana State College school of agriculture in 1965 (the first in his family to attend college). After graduation he began work as an assistant plant breeder with Robert (Bob) Matchett at Northrup King Company in Woodland, California, beginning what would be a forty-year collaboration with Bob; first at Northrup King and then at Resource Seeds, Inc. (RSI). During their twenty years at RSI, they released seventeen commercially successful wheat varieties and ten triticale varieties for California, providing yield advances that added many millions of dollars per year to the value of the state's grain and forage crops, establishing triticale as an important crop here, and sustaining the state's wheat crop during a period of intense pressure from stripe rust disease that threatened the viability of wheat production in the state.

Along with his work at RSI on "spring type" cereals for California, Oly also worked with Stan Nalepa on the breeding of the winter-type, forage triticale that became successful throughout the US, including the intermountain region of California. Oly's gift for working with everyone, and his ability to do what was needed, brought together the people and the breeding material associated with the various breeding programs in a way that greatly strengthened all of them, and produced breakthroughs like the creation of "beardless" forage triticale for California. Oly also appreciated and enjoyed collaborating with university researchers and Cooperative Extension on breeding projects as well as troubleshooting crop production problems, and he valued them greatly as colleagues and friends. As competitive as he was, when it came to breeding the best varieties he had warm relationships and productive collaboration with competing plant breeders, exchanging germplasm and addressing shared challenges.

After the sale of RSI and retirement of Bob Matchett, Oly moved to Arizona Plant Breeders to lead its barley, bread wheat, and triticale breeding programs, an opportunity that he enjoyed immensely and into which he immersed himself completely. In June of 2016, having fulfilled his planned tenure and successfully developed a pipeline of new varieties, Oly focused on helping the Arizona Plant Breeder organization with the daunting task of filling his shoes. After a long Saturday morning of field work in the Arizona heat preparing his breeding program for that transition, Oly fell ill and passed away soon after. Oly was intensely focused on breeding the very best varieties and worked incredibly hard to do so, but he also cared deeply about the people in his work and personal life and he treated them all accordingly. His generosity and joyfulness uplifted everyone who knew him.

American Society of Agronomy
California Chapter

2017 Scholarship Committee

Karen Lowell, Chair
Hossein, Zakeri
Eric Ellison

Recipients & Essays

Essay Question:

The California Department of Food and Agriculture (CDFA) Healthy Soils Initiative emphasizes that the health of agricultural soil relates to its ability to build and retain adequate soil organic matter. The USDA-Natural Resources Conservation Service (NRCS) describes four basic management principles to maintain and/or build soil organic matter:

1. Keep the soil covered as much as possible;
2. Disturb the soil as little as possible;
3. Keep plants growing throughout the year;
4. Diversify as much as possible using crop rotation and cover crops.

Write an essay that describes how you would implement these basic principles in a California cropping system. You should describe the following in your essay:

1. The cropping system (e.g. crop, irrigation type, region in which produced, etc.);
2. Detailed description of specific management practices and how they will address the principles noted;
3. Constraints a producer in California might encounter when implementing the practices as described.

You will need to research what management practices are likely to increase soil organic matter and then consider which are feasible in the CA cropping systems you have chosen. Some key practices include the use of cover crops, reduced tillage, crop rotation, irrigation water management and application of carbon-based soil amendments (e.g. compost, manure).

2017 Scholarship Winner

Suzette Nicole Turner, California State University, Chico

Cropping System Soil Health Implementation Plan

As the soil health movement continues to grow in California and globally, producers, educators, and agencies alike look towards research which identifies management practices that will address soil health most directly and thus build healthy land for sustainable cropping systems. The Natural Resource Conservation Service (NRCS) has established organic matter as the key to soil health, and there are four established principles which are the basis of maintaining and accumulating organic matter:

1. Soil coverage
2. Minimal soil disturbance
3. Continuous plant growth throughout the year
4. Building diversity through cover cropping and crop rotations

The cropping system I will focus on implementing these practices is a ten-year-old established walnut orchard on drip irrigation in the Central Valley of California. In order to establish the four above-mentioned organic matter principles, the following management strategies will be implemented :

1. A diverse continuous cycle of cover-crops throughout the year will be necessary in order to provide soil coverage, diversity, and to keep plants constantly growing at the soil surface
2. A no-till approach to cover crop planting and row management will address the minimal soil disturbance requirement
3. Minimizing the use of heavy machinery via the utilization of livestock to remove dry-matter build up will provide the least soil-disturbing method of residue management

When implementing these practices for the first time in an established orchard, it would be good to plant the first round of cover crops during the fall season after the seasons harvest and after the first rain to utilize the precipitation. The most effective cover crop for this scenario will consist of a diverse blend of nitrogen-fixing varieties like legumes and clovers, in combination with a good forage variety, as well as varieties with deep taproots, such as brassicas, that can open up the soil to allow for drainage, as well as develop better porosity and soil structure. This will require the use of a no-till drill for the planting. Planting only in the middles between tree rows will be all that is required, in order to not disturb the orchard root systems. Once planted, this cover crop can be allowed to grow until the spring.

The diversity in the cover crop is key to ideal organic matter development. With taproots opening up the soil profile, this gives access to all the other crop varieties to access previously inaccessible pore space full of untapped nutrients and mycorrhizae, which can then increase the abilities for all the crops to participate in more symbiotic partnerships within the soil community. It will stimulate the biotic activity within the soil by increasing the nutrient cycling, encouraging the soil biology to diversify and expand by providing greater variety in the carbon "cakes and cookies" for biota, as put by Dr. Elaine Ingham. The leguminous varieties will add not only to the forage quality, but will greatly improve nutrient cycling in the soil through nitrogen-fixation processes. Nitrogen fixing improves soil health by building nutrient reserves through the soil profile, providing less need for fertilizer application and thus using even less machinery on the soil.

The high quality forage will benefit the sheep that will come and graze on it, also providing rapid decomposition to the dry matter residue, which benefits the soil by adding readily available nutrient-rich organic matter. Not only do the sheep provide rapid dry matter decomposition and a good dose of fertilizer, but they also provide an intermediate amount of disturbance to the soil surface compared to the high disturbance practice of mowing with a tractor, which will compact the soil. Compaction and tillage destroys more than just pore space and the work that the deep tap rooted plants just did; it also diminishes water infiltration and damages the soil community by disrupting microbial habitat in the pore space. Limiting tractor use only to necessary practices such as harvesting, maintenance, and planting will greatly benefit the soil community and agroecosystem, allowing for the rapid development of organic matter accumulation via the practices described.

The stubble and residues left behind will hold in soil moisture and remain on the soil surface throughout the summer, protecting the soil from the sun and preventing capping and erosion. A more appropriate heat-tolerant cover crop variety mix should be planted in the residues after the spring grazing via the no-till drill once more and will need to be grazed before the harvest.

Constant monitoring of the orchard will be required in order to assess soil coverage, moisture retention, and the diversity of the ground cover quality. When it is necessary, replanting will be implemented and the sheep will be cycled through as residues build up. Performing annual soil tests is helpful when monitoring the percent organic matter change.

Constraints that will need to be addressed are numerous in any management practice implementation. For this cover crop management regime, one of the constraints will be food safety protocol for livestock introduction during the growing season. It is important to adhere to the standards established by food safety regulations in regards to exposure of the orchard crop to animals and making sure to keep a good window between sheep grazing and harvest season to avoid contamination issues. This could prove challenging if, for example, you get late summer rains that cause a growth spurt in your cover crop just before harvest, you will need to mow in order to get harvest equipment into the aisles which is causing an unnecessary use of heavy equipment and risking greater compaction.

Water is a big constraint in California. The drought has required many acres to go fallow in recent years. Orchard producers cannot provide water for both a cover crop as well as their nut crop. Some potential remedies for this would be to plant most cover crops over the winter months, to ensure enough rainfall and adequate moisture. Then, ideally, the cover crop would actually insulate the soil enough to prevent more irrigation being required for the cover crop. It would hopefully retain enough soil moisture that it would eventually cut the cost of irrigation throughout the entire orchard.

Another constraint is the high cost of a diverse cover crop seed mix. Bags of one seed variety alone can be expensive, and mixes are even more so. A way to remediate this constraint would be for the producer to analyze how they will be offsetting fertilizer costs with a cover-crop through nitrogen-fixation, as well as getting a good dose of fertilizer from the sheep passing through, and minimizing labor through minimal equipment usage and increasing water and nutrient cycling to open up the soil for water and symbiotic relationships between crops and the soil. Hopefully these benefits will outweigh the high cost of a diverse cover-crop seed mix. It will greatly minimize excessive inputs and build resilience in the agroecosystem.

Yet another constraint would be the purchasing and/or renting of a no-till drill for seeding and planting. Specialized equipment is very expensive. Just as mentioned above with the cover-crop seed mix, hopefully the investment in a machine that will greatly improve the organic matter building process will offset the initial cost with the benefits it will provide to the cropping system.

A biological constraint could be the potential for pest introduction through the implementation of a cover crop. Some brassicas and legumes themselves are considered pests when mismanaged. Also, in California, imported cabbage worm is widely recognized as a common pest that can arise when brassicas are present. Other insect pests may also become an issue from the cover crop species. Mildew can also become a problem if the cover crop is thick, overgrown, and overly moist. The concept behind a diverse cover crop could be a potential solution to all of these pest problem potentials. The intent is to not create another resource concern while addressing organic matter production. Some remedies to preventing some of these pest problems could be to do proper research and remove any species from the cover crop seeds that are well known for pest issues; and for mildew issues, a solution could be to graze more often so that proper ventilation prevents mildew establishment.

Organic matter is the key to soil health. It provides a multitude of ecosystem services such as erosion control, nutrients, maintaining microbial community health, building and preserving soil structure, improving water and nutrient cycling, providing carbon storage, and maintaining moisture and temperature control. This is only a small list of studied and verified benefits of building organic matter, for which I am sure there are many more, yet to be discovered. For any producer, it would be advantageous to invest as much time and energy as possible to developing the organic matter in the soil, while paying close attention to potential constraints and limitations. With new research showing the possibilities of carbon storage and it's connection with organic matter, leading to new carbon-storage incentive programs being established due to these findings, it seems that the best management practices for farms will soon become strategically focused on generating organic matter. I am sure that in the near future we will continue to discover ever-more effective methods for achieving these globally and microbially beneficial goals.

2017 Scholarship Winner

Samuel Koehler, University of California, Davis

My name is Samuel Koehler and I am a third year student at the University of California, Davis majoring in Plant Sciences with a specialization in Breeding and Genetics and minoring in Statistics. Since coming to Davis I have worked in a plant pathology lab studying fusarium wilt of strawberry and how crop rotation could help to eliminate this disease. I work in two other labs breeding wheat and barley, and through these experiences and my studies in plant sciences I have had a lot of experience working and analyzing farm systems. With the CDFA Healthy Soils Initiative in mind I will implement a drip irrigated crop rotation system in the Davis, California region that balances monetary crops with soil-improving crops to maintain a healthy and successful farming operation that is sustainable for the soil. Utilizing an effective crop rotation system will address each of the four points outlined by the CDFA by keeping the soil exposed to different plants, minimally tilled or disturbed, covered to ensure its health and prevent pests, and productive by keeping the field in constant rotation with beneficial plants.

My system will utilize crops such as tomato during the warm season to generate revenue and large amounts of usable plant biomass that, once the season is over, will be tilled back into the fields to incorporate this wealth of organic matter. During the cool season I will plant a combination of cereal grasses such as wheat or barley to generate revenue and cover crops such as mustard to upkeep soil nutrition and to minimize soil born pests.

With this three-to-four crop per year rotation system I will keep my fields full of plants that are growing year-round. This will ensure that I am maximizing the productivity of my land and its ability to generate revenue and nutrients to be given back to the soil. I intend to use seedlings to stagger the growth of my crops so that when one crop has been harvested I will plant the next and lose less time to early plant development and acclimation. This transplanting will also give my crops a competitive advantage against weeds and pests so that inter-plant competition is nullified. This system will require constant diligence as well as the employment of more workers to ensure that everything is running smoothly and that everything is harvested and planted on time.

The crops will be optimally covered by this constant usage, the utilization of ground covers, and by my irrigation method to prevent weed competition and soil damage/erosion. By having my fields in constant rotation I will ensure that the soil always has a level of coverage to inhibit the growth of weeds and reduce the effects of the sun on the soil. I will also use plastic sheet covers or mulches of wood chips to further keep the soil protected and weeds from gaining access to sunlight. Drip irrigation will contribute to soil health by preventing erosion caused by sprinkler or flood systems. Additionally it will disturb the soil less and more selectively water my crops over competitive weeds. Drip irrigation can be hazardous in that if it is not properly removed before the field is tilled, it will be chopped up and incorporated into the soil which is undesirable. Mulches and plastic coverings are additional costs that would have to be accounted for.

The nutrient rich crop rotation system I will utilize will cut back on the amount of tillage that will need to occur. While I will be planting more and thus disturbing the soil then because of it, my utilization of Nitrogen-fixing plants and incorporation of organic material can lessen if not remove the amount of fertilizer and compost I will need to till into my fields. In the case that my soil is deficient in something, I can try and plant a crop that naturally incorporates it back into the soil. If that is not possible can always add it myself which should be avoided whenever possible but may be done when necessary.

Crop rotation is an excellent was to diversify what crops you subject your fields to by encouraging the usage of revenue producing and soil nutrient producing plants. In addition to the crops I have outlined to use, a wide array of other crops may be implemented in place of those named if necessary depending on the problem I face. With different crops in rotation I will ensure that pests do not develop and that my soils are not damaged by mono-cropping.

The CDFA Healthy Soils Initiative outlines a set of principles that my Davis crop rotation system will show mastery of. Monetary crops such as tomato in warm seasons and barley in the cold seasons will be rotated from seedlings with nitrogen fixers like mustard to keep soils healthy and reduce the amount of fertilizer and compost tillage necessary. Utilizing a rotation system will ensure that the fields are remaining productive and diverse year round while keeping the soil covered with the help of mulches and ground covers. Problems I may face would involve those associated with pests or nutrient deficiencies. I've found through my work on farms and from the plant pathology lab I've been working in that most of these issues may be solved through tweaks in one's rotation system, substituting crops with ones that are suited to combat these issues. I am passionate about our vegetable systems and am confident that a rotation system such as the one I have outlined here will be a model for how to sustain soil as outlined by the CDFA initiative.

American Society of Agronomy

California Chapter

2017

Session # 1

Pest/Weed Management

Session Chairs:

Margaret Ellis &

Rachel Naegele

New Automated Technology has the Potential to Improve Weed Control in Vegetable Crops

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Vegetables such as broccoli, lettuce and spinach each have a few old herbicides registered, and of the few products available, the partial weed control provided must be supplemented by hand weeding and cultivation to achieve commercially acceptable weed control. Lettuce has traditionally been seeded and thinned to desired stands by a hand weeding crew with hoes. However, decreasing labor availability and increasing costs for lettuce hand thinning and weeding has resulted in need for labor saving technologies. Recently, commercial machines capable of automatic lettuce thinning have been developed to machine-thin lettuce to the desired final crop density, helping growers to reduce the ~$40 million/year spent previously to hand thin the crop. Robotic lettuce thinners typically utilize machine vision technology to detect plant location and accurately direct herbicidal sprays, such as carfentrazone to thin crops to desired stands. Within the length of the plant line, about 30% of the plants are left unsprayed, i.e., the "saved" lettuce plants which are maintained to produce the crop. However, the current state-of-the-art in this technology cannot distinguish crop from weed plants, but depends upon recognition of row patterns to detect the crop row, and rudimentary object detection for selection of unwanted crop plants for thinning. Research in Arizona and California on robotic lettuce thinners show, that while they work well in weed-free fields, their performance is limited in weedy fields, which obscure the row pattern.

Mechanical weed control has long been used for inter-row weed control but with limited ability to remove intra-row weeds. Recently introduced intelligent cultivators (ICs) are robotic image-based machines that automatically remove weeds from within the crop rows. ICs are promising new tools for integrated weed control especially for vegetable crops that are dependent on hand weeding. Integrating ICs into on-going practices is crop and region specific, and requires better understanding of their capabilities and limitations. The Robovator mechanical intra-row weed control system (http://www.visionweeding.com/robovator/) is a new IC that is already commercialized in Europe and has been introduced into California. The Robovator was evaluated in transplanted lettuce and direct seeded broccoli and was found to be effective and safe for these crops. There was no crop damage or yield reduction compared to the standard cultivator. The Robovator removed 18 to 41% more weeds than a standard cultivator and reduced hand weeding time by 20 to 45% compared to the standard cultivator. Furthermore, utilizing the IC without herbicide provided similar weed control compared to the standard cultivation plus a herbicide. These results indicate the potential of IC to improve the level of weed control provided by cultivation for both conventional and organic systems.

Current machine vision technology provides the potential for development of weed removal devices with little or no involvement of the pesticide industry. This technology opens a pathway for commercialization of weed control tools that are less encumbered by regulation than herbicides. It seems likely that intelligent technology will rival or exceed the importance of herbicides in future specialty crop weed management programs.

Detection of *Erysiphe necator* Fungicide-Resistant Alleles in Environmental Samples

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Abstract

Erysiphe necator (En) the causal agent of grapevine powdery mildew is managed using fungicides such as quinone outside inhibitors (QoIs). Unfortunately, *En* is known to develop resistance to QoIs by a single nucleotide polymorphism, resulting in an amino acid substitution (G143A) in cytochrome b. To monitor this allele, a TaqMan assay was developed and validated against powdery mildew DNA from strawberry, blueberry, snap pea, squash, Gerbera daisy, rose, and oak plants. Single spored DNA isolates (n = 103) were used to verify the accuracy of the TaqMan assay by comparing it to previous trifloxystrobin germination tests. *In-vitro* tests of single spored isolates identified 20% as the necessary proportion of the mutant allele in a mixed DNA sample to test positive for resistance. Leaf and air samples from Oregon (n = 130) were utilized in field validations. Digital droplet PCR was also utilized to quantify the allele distribution in a mixed DNA sample, lowering the necessary required concentration of the mutant allele for positive resistance identification to between 1-5% of the mutant allele. This study resulted in novel allele-specific TaqMan and Digital droplet PCR assays that detect G143A in *En*. This assay could be used to significantly reduce the labor required in dealing with leaf and air samples of *En* in the laboratory and could be used to more closely monitor resistance development for a standard management program of grapevine powdery mildew.

Integrated Pest Management: It's Time to Revisit and Renew a Familiar Concept

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For over 50 years, Integrated Pest Management (IPM) has been a very successful approach to managing pests in complex systems. However, getting agreement on what IPM is, has been and will continue to be a challenge. Born out of the demand for action to respond to increased concern about human, environmental and pest control risks posed by dependence on and widespread use of pesticides (especially insecticides), the term integrated pest management appeared in public policy in a 1972 in a message from President Nixon to Congress regarding a program for environmental protection (Kogan, 1998).

However, the concept of IPM did not appear suddenly out of the void (Kogan, 2013) but rather took many decades to develop beyond its entomological origins into the complex, multi-disciplinary, and broad scale management approach that we recognized today.

IPM is most familiar as an approach to managing pests, from very local (field, household, individual tree) to extremely broad (area wide management, consideration of landscape level influences). Perhaps as important, IPM has also served the greater society as an arbiter for addressing many complex societal issues involving pests, pesticides, and production. Over 20 years since President Nixon invoked IPM, key concerns of pesticide use as a primary control approach are still being discussed as public policy. Concerns include effects of pesticides on target organism (resistance management), pesticide effects on non-target organisms (e.g. bystanders) including beneficial insects, soil health, and the crop plant itself (Walker, et al 1995).

Thus, the very ability of the IPM construct to address such a diverse arena of issues while providing pragmatic approaches to real pest problems has led to confusion in what it really means to be doing IPM.

Defining IPM - How can 3 letters have so many meanings?

Over the decades, IPM has defined in many ways. For example, Bajwa and Kogan (2002) identified 67 definitions for IPM. However, core characteristics of those definitions include:

- Ecosystem based;
- Long term prevention;
- Combination of control techniques that minimize risks to humans, animals, and the environment;
- Monitoring pests and assessing their threat to the crop or site;

- Use of management or control techniques which present the least risk to humans, wildlife and the environment.

The pinning down a definition of IPM has been vexing because it means so many things to different people. IPM is not a monolith for solving a single problem but is a more, finessed conceptual approach. To my way of thinking,

- IPM is an approach, a philosophical, but pragmatic, description to managing system level issue;
    - IPM is platform from which we can consider options and launch solutions;
        - IPM solutions are determined by the situation.

Thus, there is no formula or recipe for IPM but rather it is a flexible approach which identifies the pest problem, evaluates the threat, assesses management options, and provides opportunity to learn, adjust, and continually improve. IPM consists of an *"IDEAL"* approach:

- Identification of the problem
- Decision-support processes
- Evaluation of options
- Assessment of actions
- Learn by reviewing the outcomes

How much IPM is enough?

If there is no hard definition against which we can measure IPM utilization, how does one know that IPM is being done? As stated, the situation determines the complexity of the solution (Kogan, 2013). Certainly, basic elements of an IPM program include identification and monitoring are, use of some decision threshold to rationalize treatment, and selection of a management or control option to protect the crop or site from substantial economic damage.

The sophistication of an IPM approach comes into play when more complexity is woven into the management approaches. In this view, preventing the problem and creating an environment in which the crop is favored over the pest, has more reflection, planning, and complicated execution than merely "*look, count, and treat*."

All decisions are restricted by the conditions facing the IPM practitioner. How much risk is the client willing to accept, how many alternatives are available, what is the value of the threat vs. the cost of treating, how quickly can the threat be moderated, how many other production issues are simultaneously being faced? Thus, the solution is not only technical but has very strong social and behavioral considerations.

So, if the degree of IPM sophistication (e.g. number of practices employed) is left to the IPM practitioner, why would progress ever be made beyond "*look, count, and treat*"? This is the very essence of the problem as well as the solution.

IPM is a platform to consider options and launch solutions. In some situations, there are many options, chemical and non-chemical and in others, very few. Depending on the situation, looking, counting and determining which is the most "benign" pesticide, represents the best IPM available. In other cases, where long term approaches are feasible more non-chemical approaches may be feasible, e.g. selection of resistant varieties, modification of planting or harvest dates (to favor the plant not the pest), modification of irrigation timing/application, or use of hedgerows /vegetative strips (to increase biodiversity and natural enemy refugia).

The drive to integrate "more" practices into an IPM program comes from the very need to demonstrate to society and policy-designers that we are using alternative practices but still require a robust pesticide "tool-box" (Goodell and Berger, 2014). Losing registration of active ingredients impacts IPM programs but overdependence on these same active ingredients increases the public concern on their use.

IPM is information intensive and requires continual research based updates to meet changes in production, regulation, and invasive pest threats. The foundation of IPM practices is science-based research and the great challenge over the past decade in California has been to maintain an independent and competitive grant process to seek solutions to existing and presumptive pest problems. The foundation of *UC IPM Pest Management Guidelines* has been the research supported by its grant program during the 1980's and 1990's, as well as commodity, state, and Federal support. The advantages of an independent competitive grant program are first, it is not driven by "problems du jour" and second, less advantaged cropping systems have an equal opportunity for funding.

How IPM planning tools can help address complex environmental and societal issues

The IPM approach requires consideration of the complexity of the system, biological, ecological, and societal. Over the years, tools have been developed which addresses the immediate or long term pest issue as well as processes to work through competing interests both internal and external to the situation.

Since 2004, UC IPM and the Natural Resources Conservation Service (NRCS) have been working together to apply IPM to resource concerns related to pest and pest management activities (Anon., 2009). These tools include:

- Development of *Watertox* (Anon., 2014), a tool modified from NRCS Pesticide Screening Tool which evaluates water related risks from insecticides;
- Working from the *Pest Management Guidelines*, UC IPM created *Year Round IPM Programs* (Anon., 2016) which provided a seasonal approach to planning IPM around multiple pests and helped NRCS conservationists utilize IPM in addressing specific resource concerns
- Developing a workbook approach (Anon., 2011) for NRCS conservationists that reviewed and allowed incorporation of an IPM program as part of NRCS' whole Farm Conservation Planning process

- Using these tools, NRCS and UC IPM could support incentives for adopting IPM practice suites to address resource issues through EQIP (Environmental Quality Improvement Program)

In addition, the *Decision Support Tool* (Anon, 2015) was recently introduced for four crops that allows the entire *Pest Management Guideline* to be mined for all IPM practices for multiple insect pests and easily links to detailed information to many tools already highlighted. This tool provides a complete overview of pest identification, threat evaluation and assessment of management options. A printable report documents your planning process is available or can be saved on portable mobile devices for later reference.

This suite of tools provides the means to evaluate real time choices but more importantly, provide a method for continual IPM improvement by allowing the PCA and property owner to reflect on and learn from what they are doing, why are they doing it, and what else could be done?

By documenting this planning activity, progress over time can be measured and uses for specific practices elucidated. By using planning tools, PCAs and property owners can address multiple and complex environmental and human health issues and provide evidence of their planning process. Such evidence directly supports the California Environmental Quality Act requirement as an environmental impact report functional equivalent statement on a pesticide recommendation to "*certify that alternatives and mitigation measures that would substantially lessen any significant adverse impact on the environment have been considered and, if feasible, adopted*" (Flint and Gouveia, 2001).

Summary

IPM is a flexible approach to managing complex system-level pest problems. It is not a monolithic set of rules but rather a methodology emphasizing prevention and long term management that emerges from reflective decision-support and planning. It can fit both the immediate needs of site specific pest management as well as addressing broader environmental and regulatory issues.

Useful Resources*:*

Anonymous. 2009. UC forges partnerships to increase IPM opportunities. UC IPM Annual Report. http://ipm.ucanr.edu/IPMPROJECT/2009/partnerships.html

Anonymous. 2011. Step-by-Step Process for Developing a Pest Management Component of a Conservation Plan. UC Statewide IPM Program.
http://ipm.ucanr.edu/PDF/PMG/NRCS_Step-By-Step_Form.pdf
http://ipm.ucanr.edu/PDF/PMG/NRCS_Step-By-Step_Instructions.pdf

Anonymous. 2014. Pesticides: Water-Related Toxicology of Active Ingredients. UC Statewide IPM Program.

http://ipm.ucanr.edu/TOX/aboutwatertox.html

Anonymous. 2015. IPM Decision Support Tool. UC Statewide IPM Program. http://www2.ipm.ucanr.edu/decisionsupport/

Anonymous. 2016. Year-round IPM programs: Video tour. http://ipm.ucanr.edu/IPMPROJECT/about_yrp2.html

Bajwa, WI and M Kogan. 2002. Compendium of IPM Definitions. What is IPM and how is it defined in the Worldwide Literature? Publication number 998. http://www.ipmnet.org/ipmdefinitions/defineIII.html

Flint, ML and P Gouveia. 2015. IPM in Practice. UC ANR Publications, Publication 3418, 296 pp.

Goodell, PB and LA Berger. 2014. Identifying and Managing Critical Uses of Chlorpyrifos Against Key pests of Alfalfa, Almonds, Citrus and Cotton. A report submitted to CDPR. 192 pp. http://www.ipm.ucdavis.edu/IPMPROJECT/CDPR_Chlorpyrifos_critical_use_report.pdf

Kogan, M. 1998. Integrated Pest Management: Historical perspectives and contemporary developments. Annual Review of Entomology 43:243-70.

Kogan, M. 2013. Integration and integrity in IPM: The legacy of Leo Dale Newsom. Am. Entomologist 59:3:150-160.

Walker, K., J. Liebman, and W. Pease. 1995. Pesticide-induced Disruptions of Agricultural Systems. California Policy Seminar publication. Center for Occupational and Environmental Health, School of Public Health, UC Berkeley.

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2017

Session #2

Nutrient Management:

Responsibilities & Liability

Session Chairs:

Karen Lowell & Ann Collins Burkholder

Understanding Grower Liability in Nutrient Management Planning

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Managing Liability for Scientific Consulting Services: Perspective of an Agronomist Working with Water Quality Coalitions

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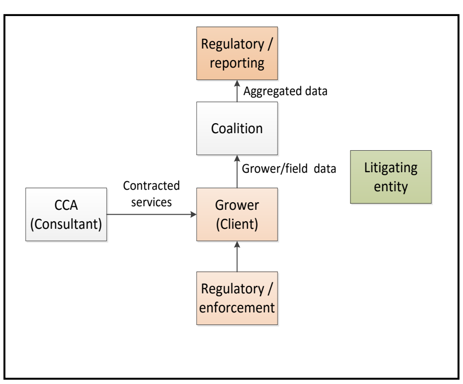
Introduction

California regional water quality control boards (water boards) have issued waste discharge requirements (WDRs) to irrigators under the Long-term Irrigated Lands Program. (LTILRP). The Central Valley water board (CVWB) allows irrigators to form water quality coalitions to represent them as groups, for purposes of collecting, aggregating, and reporting data, as well as to collectively evaluate management practices to improve the level of groundwater quality protection achieved. Among other requirements, grower/members must develop nitrogen management plans (NMPs), and may eventually be required to plan irrigation management (NIMPs). Certified Crop Advisors (CCAs) may be called upon by their clients (growers) to provide advice related to these plans, or to develop plans for growers to implement. The purpose of this paper is to provide perspective and information to help CCAs manage professional liability that could arise in the provision of these services. The perspective is that of an agronomic and soil science practitioner, having provided advice to regulated clients in a wide variety of circumstances over several decades. Companion papers contain 1) specific information on professional errors and omissions insurance, provided by a broker knowledgeable in that field, and 2) perspectives from a CCA who regularly advises growers in these capacities, and an attorney knowledgeable about the LTILRP.

Potential Liabilities

Figure 1 shows a schematic of parties involved in a regulatory system, including the CCA and grower in the context of the LTILRP. In my professional experience, the main sources of liability pertain to 1) quality of professional services rendered under a contract (usually related to a loss suffered by the client, for which the client seeks to recover damages from the consultant), and 2) actions or alleged actions by consultant during performance of services, for which client or a third party (litigating entity) may seek damages. The latter seems less common than the former.



This experience has led me to develop the following practices when performing work for regulated entities:

1. Always work under contract.
2. Carry professional insurance (general liability, errors and omissions, and auto)
3. Carefully define professional services for insurers and clients, and limiting services to provision of honest, accurate information that falls within my competence
4. Never promise a specific regulatory outcome, and include a statement that it is not assured if this could be misconstrued

5. Avoid or be prepared to reliably perform regulatory compliance tasks, such as obtaining permits for entry
6. Avoid imbalanced and/or excessive indemnification of clients (e.g., limit to the amount of the contract or contract phase)
7. Honor clients' confidentiality (e.g., let them handle, and/or participate with me, in regulatory discussions involving their permit, and never share data or work products that are not already public without their written consent)
8. Furnish clear and concise work products containing:
   - Methods and results employed
   - Summary of findings
   - Uncertainties and limits of inference associated with findings
   - Alternative and recommended actions that are legal
9. Communicate problems clearly and promptly to involved parties, and deal with them honestly and equitably
10. In the event of a claim, engage insurer immediately
11. If legal counsel is in-house or independent of insurer, then involve them, too

For me, contracts, clarity, timeliness, honesty, operating within my own expertise, allowing clients to discharge/participate in their own regulatory responsibilities while facilitating their compliance, and obtaining and working with appropriate insurance coverage, are the best means to control liability as I serve regulated clients.

In the specific context of the LTIRP, I have additionally observed the following:

1. Enforcement by regulators have been directed at growers, even when they are advised by CCAs and reporting data to coalitions. These actions have been focused on compliance with program requirements rather than on the nature or quality of data commonly provided by CCAs.
2. Efforts to obtain grower data have been directed at coalitions and their membership.
3. Other third parties have sought to meet their objectives primarily by challenging the nature or manner of implementing WDRs. These challenges have been aimed at regulatory bodies.
4. CCAs appear to take great care in responding to grower needs. If growers challenge the work of CCAs and pursue them legally, this must be relatively rare.

It appears to me that most of the tools required to manage professional liability are available to CCAs, but that a redoubled effort to establish and maintain sound practices is probably worthwhile. I am unaware of liabilities occasioned by the LTILRP are so unique that they are not routinely managed by professionals providing technical services related to other regulatory programs, by employing the types of practices I have found to be useful in these contexts. However, CCAs should seek and consider a range of input from professional organizations, legal and insurance experts, and technically competent colleagues as they develop and refine contracts, business practices, and work products suited to advising growers in the context of the LTIRP.

*contributed by conference speaker John Dickey

Key Concepts for Liability Insurance Related to Consulting Services

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"Claims Made" Nature of E&O Coverage

Unlike General Liability insurance (which is written on an "Occurrence" basis [meaning that the policy that was in effect when the allegedly negligent work was performed is the one to respond to a future lawsuit), Consultants' Professional Liability (or Errors & Omissions [E&O]) coverage is typically written on a "Claims Made" basis, which consists of two primary parts (shown on E&O Example 1 attached):

1. The policy that is in effect when the litigation is received (or claim made) is the one to respond; and

2. The allegedly negligent work must have been performed on or after the policy's "Retroactive (or Retro)" date.

Importance of the Retroactive Date

Typically, when a Consultant purchases an E&O policy for the first time, the Retroactive (or Retro) date matches the inception date of that first policy.

Then, that first Retro date remains the same for all future policy renewals – effectively adding another year of work product for coverage with each policy renewal.

For example, on E&O Example 2, you'll see a sample policy page where the "Retro Date" is 6/10/2010, for a policy that renewed in 2016. So, this policy will respond to covered litigation received during the 2016 policy year, for work product performed on or after 6/10/2010.

The important element here is that, even if a Consultant were to change insurance companies in the future, they'd want to ensure that the original Retro Date is maintained on the new insurer's policy, or else they could lose coverage for some of their older work product.

Importance of a Clear Description of "Professional Services"

As indicated on E&O Example 1, an E&O insurer will "pay on behalf of the Insured any loss and claim expenses that the Insured shall become legally obligated to pay because of (a wrongful act)."

As indicated on E&O Example 5, a "Wrongful Act" is often defined as "any negligent act, error or omission…committed solely in the render of, or failure to render, Professional Services by an insured."

So, with the policy covering “Wrongful Acts”, and “Wrongful Acts” dependent upon the definition of “Professional Services”, the importance of a clear description of a Consultant’s “Professional Services” emerges.

E&O Example 6 attached provides an example of a definition that is clear about the services to be covered under the E&O policy, stating that “Professional Services” is defined as the “performance of services as an environmental, agricultural and scientific consultant to others for a fee or other form of compensation.”

This definition was created by the broker on the application for the Consultant – i.e. it is not a “stock definition” provided by the insurer.

Accordingly, the Consultants will want to pay particular attention to the “Description of Services” area of the application, and ensure that all of his or her services are described clearly there, so that the policy’s amended definition of “Professional Services” accurately reflects their operations.

The “Retention” and the Premium

With an E&O policy, the “Retention” or “Deductible” (i.e. the first-dollar claim costs that the Consultant must bear before the insurer’s financial protection activates) must always be kept in mind when comparing premiums.

Two policies could have the same premiums, but widely different Retentions ($2,500 vs. $25,000, for example) – or the offer with the higher-costing premium could actually be better deal, because of a much lower Retention.

The premiums are fixed out-of-pocket costs for the Consultant, while the Retentions are “potential out-of-pocket” costs that accrue in the event of a claim.

A Consultant will want to be aware of both forms of out-of-pocket costs when comparing offers.

A Consultant’s Duties in the Event of a Claim

As indicated on E&O Examples 3 and 4, if a covered lawsuit should be received during a policy year, the Consultant becomes contractually obligated under the policy to perform (or not perform) certain actions. Among the more relevant of these actions are:

1. To provide written notice to the insurer as soon as practicable (and no later than 60 days after the expiration of the policy in effect at the time);

2. Not to make any payment, assume any obligation, incur any expense, or make any settlement offer without the advance written consent of the insurer;

3. Not to agree with the plaintiff to enter into arbitration, mediation, or any other form of alternative dispute resolution, without prior consent of the insurer; and

4. To cooperate with the insurer during the settlement of the claim.

Should a Consultant be sued during the policy year, he or she will want to be clear of their contractual obligations to the Insurer during the settlement process, so as to not invalidate their coverage.

Securing Coverage Beyond the Last Policy Term

With the "Claims Made" form, once the last policy cancels, the coverage essentially evaporates (since there would be no policy in effect to respond to a future lawsuit).

To address this undesirable result, Claims Made policies have built into them an "Extended Reporting Period (ERP)" provision -- known informally as "tail coverage" -- which can extend the insurance provided by the last purchased policy into the future, to address lawsuits received after the Consultant retires or discontinues his or her practice.

E&O Example 7 provides an example of a typical ERP provision, allowing the Consultant to extend the coverage of the last purchased policy up to 3 years into the future, at a preset price, as follows:

1 year of ERP coverage = 75% of last policy's premium.
2 years of ERP coverage = 125% of last policy's premium.
3 years of ERP coverage = 175% of last policy's premium.

If a Consultant wanted to extend their coverage further into the future from their last purchased policy, an additional policy can be purchased in the market which could extend the "tail coverage" up to 7 years (or for an unlimited time) into the future.

The "Discovery" Provision

Another provision in the Claims Made policy that can secure coverage into the future for a potential claim is known informally as the "Discovery" provision, which can be found in different places in the policy, depending upon the insurer (see Section “B” on E&O Example 3 for an example).

The “Discovery” provision states essentially that, if during the policy period, a situation arises that hasn’t yet turned into litigation – but has the potential to do so – the reporting of that potential claim before the end of the policy term can secure coverage under that policy, even if the lawsuit doesn’t materialize until after the policy expires.

For example, say an issue has arisen with regard to a Consultant’s work product, and it is currently a “client relationship issue” that is touchy, but not yet litigious, as the Consultant tries to remedy the situation without it resulting in litigation.

Under certain circumstances, the Consultant could report this “potential claim situation” to the insurer before the policy expires, and thus preserve coverage into the future – even after the policy terminates – if a lawsuit does, in fact, result.

The "Discovery" provision is not relevant if a Consultant remains with the same insurer at the end of the current policy term (because the Consultant can simply wait until the actual lawsuit arrives and report it to the insurer then), but it is of value if the Consultant does not renew with that same insurer – either because of the retirement of the Consultant, or a change of insurers, or because the current insurer "non-renews" the Consultant and does not offer another year of coverage.

In other words, if the Consultant is going to terminate its relationship with its current insurer at the end of the policy term, the "Discovery" provision can be a valuable tool for securing coverage into the future for litigation that has not yet materialized by the time the policy expires.

Summary

The above-mentioned aspects of a Consultant's Professional Liability (E&O) policy are the most important, in my opinion, and the Consultant who pays attention to these provisions in their policy should be well served.

Environmental Liabilities and Risk Transfer Solutions for Certified Crop Advisors

Harrison W. Scheider, V.P. & Environmental Ins Broker, American Risk Management Resources Network, LLC

"Nutrient management and the related plans CCAs are approving have changed in not only what is required for the planning process to meet standards, but also in how the public responds. This presentation is an attempt to keep you aware of the environmental liabilities that could impact you as a CCA doing nutrient management planning, either working on your own or for someone else. In either case, you need to evaluate your current insurance coverage, looking to the exclusions sections of your polices to see if coverage applies for these new environmental liabilities now affecting your business."

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Session #3

Nutrient Management

Session Chairs:

Sharon Benes & Hossein Zakeri

Availability of Nutrients in Manures

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Introduction

In Western Canada, expansion of the livestock industry over the last three decades has led to increased interest in the effective utilization of animal manures as sources of nutrients in crop production. Cattle manure originating from feedlot pens and liquid swine manure from storage lagoons are the primary manure sources on the prairies, with smaller amounts of dairy and poultry manure as these operations are restricted in number due to supply management. Benefits to crop production from the application of solid and liquid manures to provide available nitrogen (N) and phosphorus (P) in soils of the northern Great Plains have been documented (Mooleki et al., 2002; 2004, Schoenau and Davis 2006) along with micronutrients such as copper and zinc (Lipoth and Schoenau, 2007). Benefits also accrue from the provision of organic matter and sequestration of carbon in the soil (King et al., 2015). However, application of manure nutrients at rates that exceed the amounts removed in crop harvest over time results in loading and accumulation of excess soluble nitrate and phosphate in the soil that is susceptible to loss by leaching and run-off. Only a portion of the manure nutrient is in, or becomes, a soluble form that is available for plant utilization or movement in water across the soil surface or through the soil profile. Therefore there is a need to understand the degree to which manure nutrients are rendered “available” for uptake and transport in order to manage manures for maximum crop benefit and minimum entry to water and air.

Managing Manure as a Fertilizer

Manures are challenging plant nutrient sources due to their dilute nature (typically only 1-2% nutrient concentration or less on a wet basis), variable composition, and restrictive balance of nutrients relative to crop requirements (typically too much P relative to N). Effective utilization of manure nutrients in crop production requires knowing the composition of the manure and how it behaves. This is best accomplished through manure analysis of total and available nutrient content, and input of this information into predictive models of available nutrient release through mineralization.

Availability of Nitrogen

In most manure sources, the primary forms of nitrogen are ammonium and organic N. Nitrate is formed in the soil following manure application through nitrification of the ammonium added or produced in the soil through mineralization of the organic N. Liquid effluents such as liquid swine manure contain a large proportion of their nitrogen in the form of ammonium that is immediately available for plant uptake or conversion to nitrate if not used by the crop (Stumborg et al., 2007). A prediction of availability of N in liquid swine manure effluent for the year of application in the northern Great Plains is 100% of the ammonium N and 30% of the organic N (Qian and Schoenau, 2000). Given ammonium contents in liquid effluents that may approach 70% or more of the total N, it is not surprising that crop recoveries of liquid manure N in the season of application come close to commercial fertilizer N sources like urea (Mooleki et al., 2002). On the other hand, solid cattle manures contain most of their nitrogen in organic forms that must be mineralized to be rendered plant available. The carbon to nitrogen (C:N) ratio of the manure is an easily measured predictor of the rate of nitrogen release to be anticipated from manures and composts (Qian and Schoenau, 2002). A general guideline is that a C:N ratio of <13 is typically associated with a net release of available N (mineralization) in the first few weeks following application while a C:N > 15 results in an initial temporary tie-up (immobilization). Over several years of manure application, as humic materials build-up in the soil with narrowing C:N ratios due to respiration, release of available N from mineralization increases gradually. In Western Canadian soils, due to cattle manure with a high content of bedding straw and cold temperatures, only about 10% of the available N may be released into plant available forms from the manure during the year of application (Mooleki et al, 2004).

The differences in release rates of available N between liquid effluent (swine) and solid manure (feedlot cattle) and its influence on accumulation of nitrate in the soil are shown in Table 1. Note that the agronomic rate of liquid effluent (37,000 L ha^{-1} or ~100 lbs N/ac/yr for 8 years) shows no accumulation of nitrate while the amount applied that is greatly in excess of crop removal (148,000 L ha^{-1} or ~400 lbs N/ac/yr for 8 years) results in large accumulation of nitrate in the top 60 cm and evidence of translocation well below this depth. However, due to the low ammonium content of solid cattle manure and low rate of mineralization due to high C:N ratio, neither the 100 lb N/ac/yr (7.6 Mg ha^{-1}) or 400 lb N/ac/yr (30.4 Mg ha^{-1}) for 8 years treatments are showing accumulations of nitrate in the surface or at depth above the unfertilized control. However, release of available N from mineralization in the soils is gradually increased over time, and will continue for several years after application of the solid cattle manure ceases.

Table 1. Nitrate - N (NO_3^- - N) distribution in the soil profile (0- to 150-cm) following eight annual applications of liquid swine effluent or solid feedlot cattle manure to a Black Chernozem in a cereal-oilseed rotation in Saskatchewan, Canada. Note: 37,000 L ha^{-1} of liquid swine manure effluent and 7.6 Mg ha^{-1} of solid cattle manure is equivalent to ~100 lbs N/acre and 148,000 L ha^{-1} and 30.4 Mg ha^{-1} is equivalent to ~ 400 lbs N/acre (Stumborg et al., 2007).

LIQUID SWINE EFFLUENT

	2*M* KCl			
	kg NO_3^- - N ha^{-1}			
Treatment	**0- to 60-cm**	**60- to 90-cm**	**90- to 120-cm**	**120- to 150-cm**
Control	7	2	2	8
37,000 L ha^{-1} Injected yr^{-1}	10	5	8	10
74,000 L ha^{-1} Injected yr^{-1}	104	57	27	11
148,000 L ha^{-1} Injected yr^{-1}	440	178	53	23
112 kg N ha^{-1} Urea yr^{-1}	71	42	16	12
LSD $_{(0.10)}$	109	24	23	11

SOLID CATTLE MANURE

	2*M* KCl			
	kg NO_3^- - N ha^{-1}			
Treatment	**0- to 60-cm**	**60- to 90-cm**	**90- to 120-cm**	**120- to 150-cm**
Control	15	3	5	6
7.6 Mg ha^{-1} B&I yr^{-1}†	16	3	5	7
15.2 Mg ha^{-1} B&I yr^{-1}	14	4	4	5
30.4 Mg ha^{-1} B&I yr^{-1}	24	6	9	15
112 kg N ha^{-1} Urea yr^{-1}	44	26	26	31
LSD $_{(0.10)}$	27	21	21	20

† Denotes broadcast and incorporate application.

Availability of Phosphorus

Like nitrogen, phosphorus in manures exists in inorganic and organic forms. Soluble forms of phosphorus in manure include inorganic orthophosphate and low molecular weight organic P compounds. Insoluble P forms are generally organic materials and also some solid-phase P -

containing minerals such as calcium and magnesium phosphates. For many manure sources, estimates of available P for crop utilization are based on measurement of the soluble P fraction typically through a water or weak salt extraction and also from supply rates of available P measured in manure amended soils (Qian and Schoenau, 2000). In Western Canada, P availability from liquid manures in the year of application are estimated to be around 50% of that of P applied as commercial fertilizer, with a range of 20-80% (Schoenau and Davis, 2006). This reflects low solubility of some inorganic P bearing minerals in the manure as well as incomplete mineralization. Owing to a low N:P ratio of solid cattle manures (~3:1) compared to crop N:P requirements of ~8:1, we observe significant accumulation and increases in the labile P levels in prairie soils after a few years when applied to meet N requirements, even at low (agronomic N) rates (Table 2).

Table 2. Labile phosphate-P amounts and supply rates in the 0-15 cm depth of a Black Chernozem in Saskatchewan following eight annual applications of liquid swine effluent and solid cattle manure at agronomic (~ 100 kg N $ha^{-1}yr^{-1}$) and excessive (~ 400 kg N $ha^{-1}yr^{-1}$) rates (Stumborg and Schoenau, 2008).

Treatment	**$NaHCO_3$ extractable**		**Plant Root Simulator™**
	Inorganic P	**Organic P**	**Supply Rate**
	(kg · ha^{-1} 0-15 cm)		(µg P cm^{-2} d^{-1})
Control	3.2	3.8	0.7
Urea @ 100 kgN ha^{-1}	1.1	6.7	0.5
Swine manure @ 100 kgN ha^{-1}	3.0	8.3	0.9
Swine manure @ 400 kgN ha^{-1}	21.0	25.4	1.7
Cattle Manure @ 100 kgN ha^{-1}	22.5	27.2	2.9
Cattle Manure @ 400 kgN ha^{-1}	44.5	58.0	4.2
LSD $p \leq 0.10$	*7.9*	*11.7*	*0.9*

Availability of Potassium, Sulfur and Micronutrients

Animal manures are good sources of available potassium (K), with the availability of potassium considered to be 90 to 100% in the year of application (Schoenau and Davis, 2006). This results in high supplies of available K in soils receiving repeated applications of manure at high rates, with reported increases in the tetany ratio: K/ (Ca+Mg) of cereal straws grown on soils receiving excessive rates of cattle manure (Qian et al., 2005).

While solid cattle manures can generally supply sufficient amounts of plant available sulfate for crop production, some liquid effluents are reported to be low in available S compared to available nitrogen (Schoenau and Davis, 2006). This is attributed to anaerobic conditions during effluent storage that result in conversion of available sulfate to insoluble sulfides. Therefore, high S demanding crops (e.g. *Brassicae* spp.) have sometimes been observed to respond to supplemental commercial S fertilizers when liquid effluents are applied to S deficient soils (Schoenau et al., 2010).

Animal manures contain and directly add to the soil several micronutrients including copper, iron, manganese and zinc. Manures can also influence micronutrient availability and uptake through their influence on soil pH, root growth and exudates, nutrient balance and competition for root absorption sites (Del Castilho et al., 1993). Concentrations of labile copper and zinc in prairie soils were observed to be increased in the soil after only three to five years of annual cattle manure applications (Qian et al., 2003). Liquid effluents were also reported to increase the soil and plant tissue concentrations of copper and zinc, with increases related to the rate of application, as the manure was a direct source of copper, zinc, manganese and iron (Lipoth and Schoenau, 2007). Manure application also did not have an effect on the non-essential elements selenium, arsenic and mercury in the soil or plants. It was concluded that metal loading and plant accumulation and toxicity was not a concern after five to seven years of application of liquid swine effluent or solid cattle manure to prairie soils at agronomic rates.

Recommendations

Analysis of the manure source to provide individual nutrient concentrations, predicted availability and balances will be useful in fine tuning the application of manure and commercial fertilizer to meet crop nutrient requirements in a rotation. Monitoring manured soils over time is recommended to provide a basis for adjusting rates to reduce nutrient loading, waste and losses to water and air. Plant tissue concentrations reflect the effect of manure applications on increasing availability of nutrients and can be used as another means of determining if the manure application approach is successful in promoting plant uptake of the nutrients.

Literature Cited

Del Castilho, P., Chardon, W.J., and Salomons, W. 1993. Influence of cattle-manure slurry application on the solubility of cadmium, copper, and zinc in a manured acidic, loamy-sand soil. J. Environ. Qual. 22:689-697.

King, T.N., J.J. Schoenau and Malhi, S.S. 2015. Effect of application of liquid swine manure on soil organic carbon and enzyme activities. Sust. Agric. Res. 4: 13-25.

Lipoth, S.L. and Schoenau, J.J. 2007. Copper, zinc and cadmium accumulation in two prairie soils and crops as influenced by repeated applications of manure. J. Plant Nutr. Soil Sci.170: 378-386.

Mooleki, S.P., Schoenau,J.J., Hultgreen, G., Wen, G. and Charles, J. 2002. Effect of rate, frequency and method of liquid swine manure application on soil nitrogen availability, crop performance and N use efficiency in east-central Saskatchewan. Can. J. Soil Sci. 82: 457-467.

Mooleki, S.P., Schoenau, J.J., Charles J. and Wen, G. 2004. Effect of rate, frequency and incorporation of feedlot cattle manure on soil nitrogen availability, crop performance and nitrogen use efficiency in east-central Saskatchewan. Can. J. Soil Sci. 84: 199-210.

Qian, P. and Schoenau, J.J. 2000. Use of ion exchange membrane to assess soil N supply to canola as affected by addition of liquid swine manure and urea. Can. J. Soil Sci. 84: 213-218.

Qian,P. and Schoenau, J.J. 2000. Effect of swine manure and urea on soil phosphorus supply to canola. J. Plant Nutr. 23: 381-390.

Qian, P., Schoenau, J.J., Wu, T. and Mooleki, S.P. 2003. Copper and zinc amounts and distribution in soil as influenced by application of animal manure in east-central Saskatchewan. Can. J. Soil Sci. 83: 197-202.

Qian, P. and Schoenau, J.J. 2002. Availability of nitrogen in solid manure amendments with different C:N Ratios. Can. J. Soil. Sci. 82: 219-225.

Qian, P, Schoenau, J.J., King, T. and Japp, M. 2005. Effect of repeated manure application on potassium, calcium, and magnesium in soil and cereal crops in Saskatchewan. Can. J. Soil Sci. 85: 397-403.

Schoenau, J.J. and Davis, J.G. 2006. Optimizing soil and plant responses to land-applied manure nutrients in the Great Plains of North America. Can. J. Soil Sci. 86: 587-595.

Schoenau, J.J., Carley, C., Stumborg, C. and Malhi, S.S. 2010. Strategies for Maximizing Crop Recovery of Applied Manure Nitrogen in the Northern Great Plains of North America. Pages 95-107 In. Recent Trends in Soil Science and Agronomy Research in the Northern Great Plains of North America Kerala: Research Signpost.

Stumborg, C., Schoenau, J.J. and Malhi, S.S. 2007. Nitrogen balance and accumulation pattern in three contrasting prairie soils receiving repeated applications of liquid swine and solid cattle manure. Nutr. Cycl. Agroecosyst. 78: 15-25.

Stumborg, C. and Schoenau, J.J. 2008. Evaluating phosphorus loading from repeated manure applications to two Saskatchewan soils. Can. J. Soil Sci. 88: 377-387.

Nitrogen Technologies for Improving N Use Efficiency in Leafy Green Vegetable Production

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Introduction

Vegetable growers are under pressure to improve nitrogen use efficiency (NUE) and reduce losses of nitrate in surface runoff and leaching to groundwater. Regulations implemented by Central Coast and Central Valley Regional Water Quality Control Boards are prompting growers to evaluate ways to bring nitrogen (N) application rates closer to the N uptake of their crops. Basic agronomic practices such as maintaining nitrate in the root zone with careful irrigation management, as well as measuring and accounting for residual soil nitrate in fertilizer programs can greatly improve NUE of vegetable production. Fertilizer technologies such as nitrification inhibitors and controlled release fertilizers have the potential to provide additional improvements in NUE. Nitrification inhibitors are commonly used in the corn belt of the US and in Europe to reduce N losses via volatilization of urea and ammonical fertilizers, losses via denitrification, as well as nitrate leaching (Wolt 2004). Nitrification inhibitors slow the transformation of ammonium to nitrate by disrupting the action of *Nitrosomonas* and *Nitrobacter* bacteria that carry out this transformation. As a result, a greater portion of fertilizer N potentially stays as the positively charged ammonium molecule which binds to negatively charged clay particles and organic matter thereby making it less likely to leach with excessive rainfall or irrigation. Examples of nitrification inhibitors include nitrapyrin, dicyandiamide (DCD) and dimethlpyrazolphosphate (DMPP) (Table 1). Nitrapyrin and DCD are used extensively in the Midwest, and DMPP is used in Europe. Nitrification inhibitors biologically degrade over time and lose their effect, and their longevity depends on soil temperatures and moisture with faster degradation in warmer soils. Given the action of nitrification inhibitors on the bacteria in the soil, some are classified as pesticides and must go through the EPA registration process. Others such as DCD are not classified as pesticides and do not require registration. In addition to these products, there are other chemicals such as thiosulfates which are also reported to inhibit nitrification (Goos 1985). There are also products that blend urease inhibitors with nitrification inhibitors to slow the breakdown to urea to ammonium (Bremmer and Douglas 1971).

Controlled release N fertilizers include polyurethane coated urea prills and urea polymers. The polymer coated urea products are rated by the average number of days it takes to achieve maximum release of N from the prill. This is typically regulated by the thickness of the plastic coating with thinner coatings providing more rapid release. Urea polymers are chains or ring formulations that slow the release of ammonium from urea and give it more residence time in the soil.

Nitrogen technology materials operate in the soil which is a complex biological system with changing temperatures and moisture conditions. These factors affect the performance of the materials and can make prediction of how well they will perform difficult. The vast majority of research on nitrification inhibitors has been conducted on agronomic crops in the corn belt, however in the 1970's and 1980's Welch and others conducted studies with nitrapyrin on cauliflower, cabbage, celery, lettuce and strawberries on the central coast. Their work showed increased yields of these crops at the same rate of N fertilization with nitrapyrin amended fertilizer (Welch et al 1979; Welch et al 1983; Welch et al 1985a; and Welch et al 1985b). Nitrapyrin was not registered for use on those horticultural crops at that time, and since then production practices have changed (no furrow irrigation and greater use of drip irrigation on lettuce).

Clipped spinach is produced on high density 80-inch wide beds that are sprinkler irrigated. Spinach typically matures in 25 to 30 days during the summer and takes up from 80 – 100 lbs N/A. The majority of N is taken up in the last 2 weeks of crop cycle. The majority of active roots of spinach are 4 to 8 inches deep. Spinach has strict quality requirements necessitating deep green leaf color and no tolerance for yellow nitrogen deficient leaves. Romaine lettuce matures in 60-65 days during the summer. Six-seedline romaine grown on 80-inch wide beds takes up from 140 to 170 lbs N/A. It takes up very little nitrogen during the first 30 days of the crop cycle and takes up the majority of nitrogen during the final 30-35 days. The majority of active roots of lettuce are 8 to 15 inches deep.

To understand the performance of nitrapyrin and other nitrogen technologies with current production practices for leafy vegetables, trials were initiated in 2012 and this report describes the results of evaluations on a number of nitrification and controlled release materials in spinach and lettuce production systems.

Materials and Methods

Trials were conducted from 2012 to 2016. Spinach trials were all conducted in commercial production fields with cooperating growers and lettuce trials were conducted at the USDA research station south of Salinas. Trial sites were selected with low residual soil nitrate-N. A standard N fertilizer treatment was included in all trials and compared with a moderate N fertilizer (25 to 35% less N) designed to not supply sufficient N for optimal yield. All nitrogen technology fertilizer treatments were applied at the moderate N rate in order to be able to determine if they provided a boost in yield over the unamended moderate rate. Materials tested in these trials are listed in Table 1. Summaries of the 2012 to 2015 trials were made of 7 spinach and 4 lettuce trials. Summaries included comparisons of average yields of nitrogen technology treatments with the standard and unamended moderate fertilizer N treatments.

The 2016 lettuce trial was conducted at the USDA Research Station south of Salinas. The variety 'Sun Valley' was seeded on June 21 sprinkler irrigated until thinning on July 15. Surface drip irrigation was installed on July 21 and was used to irrigate and fertigate the crop for the remainder of the crop cycle. Fertilizer was applied to specific treatments in two ways: 1) dry fertilizers shanked in the first application (July 19, using a Fairbanks small-plot applicator) followed by liquid fertilizer injected into the drip system for the second application (August 5); and 2) liquid fertilizer injected into the drip system for both the first (July 22) and second (August 5) fertilizer applications. Fertilizer used for all fertigations was urea ammonium nitrate (UAN 32). A 12 mainline manifold was used to apply the fertilizers to each treatment and to keep the treatments separate. Nitrapyrin at 0.5 and 1.0 lbs a.i./A was applied in three methods: 1) total quantity of nitrapyrin was applied to ammonium sulfate crystals and applied as a dry material, 2) total quantity of nitrapyrin was applied in the first fertigation only, and 3) the total quantity of nitrapyrin was split between the first and second fertigation. Each plot was two 40-inch beds wide by 100 feet long and all treatments were arranged in a randomized complete block design with four replications. All experimental fertilizer treatments were applied at a moderate fertilizer amount (80 lbs N/A) and were compared with an unamended treatment also applied at 80 lbs N/A and a standard treatment applied at 150 lbs N/A. The field was irrigated with 130% ET which supplied excess irrigation water which tested the materials ability to maintain a greater percentage of the mineral N as ammonium which is less likely to leach. Lettuce was harvested on August 23 by cutting thirty six heads from each plot, weighing them and subsampling them for dry weigh and total N content.

Results

There was a good response to applied nitrogen across the trials in both spinach and lettuce (Table 2). The standard treatment increased the yield of spinach over the moderate treatment by 12.8% and 11.1% for lettuce. Most nitrogen technologies improved the yield of moderate N fertilizer spinach treatment between 3 to 7%, except urea triazone which had lower yield. All nitrogen technologies improved the yield of moderate N fertilizer lettuce treatment between 1 to 7%. Interestingly, urea triazone had the lowest yield in spinach but the greatest improvement in yield in lettuce. These trials indicate that nitrogen technologies helped maintain or improve yields to some extent when a lower-than-optimal rate of N was used. This is an important point because it indicates that nitrogen technologies are accomplishing their goal of improving NUE and can help growers use lower rates of N and still maintain adequate yields. However, yield improvements observed in these trials are averaged across a number of trials and do not guarantee success in a given field because variability in irrigation efficiency, soil conditions and temperature may affect the efficacy of the materials.

Mineral nitrogen evaluations of the various N technology treatments did not always show higher levels of ammonium and lower nitrate levels as might be expected based on the mode of action (McCarty 1999) of the materials (data not shown). However, yield evaluations may give an indirect indication that nitrogen technologies provided environmental benefits such as reductions in nitrate leaching and nitrous oxide emissions on the assumption that improvements in NUE result in environmental benefits. Other researchers that have examined the environmental benefit of nitrogen technologies and have shown their benefits parallel the improvements in yields (Wolt 2004).

How long nitrification inhibitors remain active in soil is not clear. These trials were conducted in the summer months when soil temperatures are in the mid-60's to 70's. Studies indicate that nitrification inhibitors are more successful in cooler soil temperatures and are therefore more used in the more northern reaches of the corn belt (Wolt 2004). It is possible that the effect of nitrification inhibitors may be limited by their longevity in the soil. We saw some indication that this might be the case in the 2016 lettuce trial where splitting nitrapyrin between the first and second fertigation gave improved yields over putting the entire amount on in the first fertigation alone (Table 3). These results may give support to the need for spreading the activity of this material over more of the production cycle.

Summary

Careful irrigation management and use of fertilizer rates that account for residual nitrate levels are basic N management practices. These studies indicated that N fertilizer technologies can provide additional benefits to improving NUE in vegetable production. On average, we observed that N technologies can provide modest improvements in NUE. However, questions remain regarding the longevity of their activity in the soil and more research needs to be done about how best to apply the materials to vegetables in warm summer soil conditions. The results from these trials indicate that nitrogen technologies can provide growers a tool to assure that they maintain yields while reducing N fertilizer rates. Ultimately, nitrogen technologies do not replace but enhance basic agronomic practices which lead to good yields, environmental benefits and economical production.

Table 1. Nitrogen technology materials used in these studies

Material	Trade name	Rate	Comment
Nitrification inhibitors			
Nitrapyrin	Instinct	0.5 to 1.0 lb a.i./A	Inhibitor or Nitrosomonas and Nitrobacter, commonly used in the cornbelt
DMPP	Novatec	0.8% on AS[1]	Inhibitor or Nitrosomonas and Nitrobacter. The active ingredient is commonly used in Europe
DCD + urease inhibitor fertilizer additive	Agrotain Plus	15 lbs/ton UAN-32	DCD is the nitrification inhibitor and is mixed with a urease inhibitor; used as a fertilizer addative
DCD + urease inhibitor impregnated urea prill	Super U	@ fert rate	DCD is the nitrification inhibitor and is mixed with a urease inhibitor; formulated as a dry prill
Controlled release			
Polymer coated urea prill	Duration 45	@ fert rate	Polyurethane coated urea prill
Urea triazone	N-Sure	50:50 with UAN-32	Ring of urea molecules; liquid formulation

1 – ammonium sulfate

Table 2. Performance of nitrogen technology treatments relative to standard[1] and moderate[2] N treatments. Data represents the mean performance across 7 spinach and 4 lettuce trials

Treatments	Spinach		Lettuce	
	Relative to Standard	Relative to Moderate	Relative to Standard	Relative to Moderate
Untreated	61.3	69.0	66.1	77.6
Standard[1]	100.0	112.8	100.0	111.1
Moderate[2]	89.0	100.0	83.1	100.0
DCD + urease inhibitor fertilizer additive	---	---	84.2	101.0
Polymer coated urea prill	95.0	107.4	89.1	95.6
DCD + urease inhibitor impregnated urea prill	93.4	103.7	---	---
Urea triazone	66.8	76.7	97.1	107.5
Nitrapyrin	93.5	103.8	94.4	104.8
DMPP	95.4	104.7	93.7	105.3

1 – Used a typical rate to achieve maximum yield; 2 – 25-35% less than the standard rate.

Table 3. 2016 romaine lettuce evaluation

Material	Nitrapyrin application timing	Total N/A	Fresh Biomass tons/A	Head wt lbs	Dry Biomass lbs/A	N uptake lbs/A
Standard	---	150	28.313	1.81	2,814.9	102.4
Moderate	---	80	23.566	1.50	2,458.1	80.6
Nitrapyrin 0.50 lb ai[1]	1st app.	80	23.832	1.52	2,573.9	82.0
Nitrapyrin 1.0 lb ai[1]	1st app.	80	24.619	1.57	2,519.7	80.6
Nitrapyrin 0.50 lb ai[2]	1st & 2nd app.	80	25.363	1.62	2,592.4	83.3
Nitrapyrin 1.0 lb ai[2]	1st & 2nd app.	80	25.727	1.64	2,758.9	86.3
LSD $_{0.05}$			ns	ns	ns	ns

1 - Total quantity of nitrapyrin applied in the first application in UN32; 2 – total quantity of nitrapyrin split between 1st and 2nd applications in UN32

Literature Cited:

Bremmer, J.M. and L.A. Douglas. 1971. Inhibition of urease activity in soil. Soil Biology and Biochemistry 3(4):297-307.

Goos, R.J. 1985. Identification of ammonium thiosulfate as a nitrification and urease inhibitor. Soil Science Society of America Journal 49(1):232-235.

McCarty, G.W. 1999. Modes of action of nitrification inhibitors. Biology and Fertility of Soils 29:1-9.

Welch, N. K.B. Tyler and D. Ririe. 1979. Nitrogen stabilization in the Pajaro Valley in lettuce, celery and strawberries. California Agriculture: September, 12-13.

Welch, N. K.B. Tyler, D. Ririe and F. Broadbent. 1983. Lettuce efficiency in using fertilizer nitrogen. California Agriculture: November-December, 18-19.

Welch, N. K.B. Tyler, D. Ririe and F. Broadbent. 1985a. Nitrogen uptake by cauliflower. California Agriculture: May-June, 12-13.

Welch, N. K.B. Tyler, and D. Ririe. 1985b. Cabbage yield and nutrient uptake. California Agriculture: July-August, 30-31.

Wolt, J.D. 2004. A meta-evaluation of nitrapyrin agronomic and environmental effectiveness with emphasis on corn production in the Midwestern USA. Nutrient Cycling in Agroecosystems 69:23-41.

Zinc nutrition in perennial plants: a historical and current research review

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American Society of Agronomy

California Chapter

2017

Session #4

Complex Issues in Agriculture

Session Chairs:

Dan Munk, Stan Grant &

Robert Hutmacher

Comparing Sustainable Farming to Conventional, Organic, and Biodynamic Farming

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Introduction

If I were to assemble 50 people in a room, including growers, environmentalists, consumers, scientists, and government regulators, and ask them to define sustainable farming I would likely get 50 different definitions. One of the challenges in creating a definition is figuring out its scope. Sustainability involves all activities undertaken on the farm and how they affect its economic viability, its environmental impacts, and its effects on all aspects of human resources, from employees to the surrounding community. Opinions differ greatly on which ones are the most important. Another challenge is that for some, certain aspects of sustainable farming are value-based, while others feel it needs to be all science-based. And finally, not all farming practices can be evaluated by applying economics, environmental effects and social impacts in equal measure.

Comparing the paradigms of sustainable, conventional, organic and Biodynamic farming is challenging under any situation but to do so in six pages or less is particularly difficult. I will attempt to do so by discussing their evolution because one will see they are all related to each other and share common roots, so to speak.

Based on my experience working with growers to develop a regional sustainable winegrowing program, there are three challenges to overcome in relation to sustainable farming: 1) Defining it, 2) Implementing it on one's farm, and 3) Measuring its effects on the crop, the production field, the surrounding environment, and the grower's economic bottom line. This presentation will focus on the first challenge because if one cannot define sustainable farming it will not be possible to implement on the farm.

Evolution of Organic Farming

When defining sustainable farming we need to look at the history of organic farming, since they share a common ancestry. The present paradigm of organic farming began as a melding of several different schools of thought that were supported by European and English scientists active in the 1920s, 30s and 40s. Opinions differ as to who really started the organic movement, with at least two people, both British, being bestowed the title of founder: Lady Eve Balfour and Sir Albert Howard. Both practitioners emphasized the role of a healthy, fertile soil in viable agriculture. Howard developed many of his ideas in India prior to World War II where he was trying to meet the challenge of improving farmers' yields in order to feed a rapidly increasing population. He believed the best way to increase food productivity at a moderate cost was to return the organic by-products of crop production as well as animal manures to the soil. Howard also had concerns

about the changes in soil chemistry caused by the use of synthetic fertilizers and the use of chemical pesticides to solve all pest problems (Francis and Youngberg 1990; Rodale 1973).
In the US, organic certification is now a nationally recognized program under the USDA. The basic organic crop standards are (https://www.ams.usda.gov/publications/content/organic-production-handling-standards):

- Land must have had no prohibited substances applied to it for at least 3 years before the crop can be certified organic
- Soil fertility and crop nutrition are managed through tillage and cultivation practices, crop rotation, and cover cropping. This can be supplemented with animal and crop waste materials
- Crop pests, weeds, and diseases are controlled primarily though physical, mechanical and biological controls. When necessary organically approved pesticides can be applied
- Use of genetic engineered materials, ionizing radiation, and sewage sludge is prohibited

The Emergence of Sustainable Agriculture

In the 1950s and 1960s another movement, called the Green Revolution, evolved to meet the challenge of providing food for a rapidly expanding world population. This movement met the challenge from a direction that was diametrically opposed to that of organic farming. It emphasized genetically enhanced plant varieties (from conventional genetic breeding programs) and high energy off-farm inputs such as mechanization, synthetic fertilizers and pesticides. In time this movement became ‘conventional’ agriculture and resulted in high food production at a low cost to the public (Parayil 2003). As this farming paradigm evolved some people became concerned that this type of agriculture could not be sustained in the long term. They felt that although the cost of food production was low, the dollar value of food produced with conventional agriculture did not reflect the true cost from an ecosystem and societal perspective. They proposed that true cost takes into consideration issues like air pollution from producing and using fossil fuels, soil degradation due to intense cultivation and use of synthetic fertilizers, habitat destruction, air and ground water contamination with fertilizers and pesticides, and the steady decrease of the farmer population as small family farms were out-competed by large corporate farms. These concerns over the long-term viability of conventional agriculture accelerated the evolution of the sustainable agriculture movement.

Rudolf Steiner and the Establishment of Biodynamic Farming

To understand Biodynamic farming one must understand Rudolf Steiner. Many people are responsible for the evolution of the other farming paradigms. However, the principles and practice of Biodynamic farming are attributable to only one person - Rudolf Steiner. Biodynamics can be traced directly back to a series of 8 lectures developed and presented by him in June of 1924 to a group of European farmers who came to him for advice on soil fertility problems, degenerate seed strains and the spread of animal disease. Steiner died in early 1925 and others have carried on his system of farming. To fully appreciate what is behind Biodynamic farming, it is important to understand Steiner the philosopher and scientist.

Rudolf Steiner was born in 1861 in a small town in what is now Croatia. He went to technical school as a youth and was well grounded in the natural sciences. Out of his own interests he began reading a great number of philosophy books. He became convinced that it was only through the philosophical method that the material and spiritual worlds would be bridged. Throughout his advanced studies in math, natural history and chemistry he continued his keen interest in the work of contemporary philosophers. He saw a constant interplay between the material and spiritual worlds. He obtained a Ph.D. in 1891 and taught history, German literature, and the history of science in Berlin for several years. In 1902 he declared in a lecture that his life's aim was to found new methods of spiritual research based on science. Since Steiner was trained as a scientist and dedicated to the investigative standards of scientific research, he strove constantly to apply corresponding rigor to his own investigations (Childs, 1995). Steiner referred to himself as a 'spiritual researcher' and felt that the body of knowledge he accumulated was genuine 'spiritual science'. He coined the term "anthroposophy" as the name of this science. Steiner defined anthroposophy as "a path of knowledge that strives to lead the spiritual in man to the spiritual in the universe" (Koepf 1976).

Steiner's views were considered by many of his contemporaries to be controversial and there was strong opposition to them, to the point of threats being made on his life. Some felt he was associated with the occult. He began lecturing on diverse topics such as religion, education, social issues, history and human nature. Many sympathizers began to desert him. However, by January 1905, his adherents considered the depth of his knowledge of the material and immaterial worlds was such that invitations to give lectures poured in and his life work had begun (Childs, 1995).

Around 1917, Steiner began another phase of his career, devoting his time to putting his spiritual-scientific principles and knowledge to practical use. For example, he was approached by the managing director of the Waldorf-Astoria cigarette factory in Stuttgart, Germany, to direct a school for the children of factory employees. To accomplish this he started the Waldorf/Steiner school in 1919 and developed an educational system based on anthroposophy. There are now Waldorf schools all over the world. In 1920 he was asked by a doctor to develop a series of lectures for doctors and medical students on various aspects of human anatomy, physiology, and pathology as well as diagnoses and appropriate remedies, including developing some pharmaceuticals. Then in 1924, one year before his death, Steiner gave his series of 8 lectures that became the basis for Biodynamic farming.

Steiner took a holistic approach to farming. He felt that since plants germinate, grow and produce fruit and are dependent on the sun, earth, air and water to do so, then literally the whole universe is involved in these processes. In his mind, yield and quality of crops come about under the influence of two groups of environmental factors: earthly and cosmic. He saw each farm as an individual organism which should be as self-sufficient as possible. For example, a Biodynamic farm should have a diversity of crops and a certain amount of livestock. Because a farm is a living organism he reasoned that only 'life-endowed' substances should be applied to it. 'Dead' materials such as chemical fertilizers and synthetic pesticides should not be used. Therefore only organically derived materials should be used in farming and it is in this aspect that Biodynamic farming has a commonality with organic farming.

One important practice that sets Biodynamic farming apart from other farming practices, is the use of 9 specific preparations of materials developed by Steiner to add to composts, to the soil or sprayed on plants, depending on the preparation. The amount of the preparation applied is small because he felt that they worked "dynamically," regulating and stimulating processes of growth. Steiner gave each preparation a number from 500 to 508 and they are divided into two groups. The first group consists of Nos. 500 and 501 and each is applied in spray form. No. 500 consists of dairy cow manure collected in early autumn, packed into a cow's horn, buried in a pit in biologically active soil for the winter and dug up in the spring. No. 501 consists of ground quartz mixed with rain water to make a paste which is then packed into a cow's horn, ideally from a cow that has calved a number of times but not more than 8 years old. The horn is then buried in the late spring in a sunny spot and dug up in late autumn. Both 500 and 501 are made into a spray by mixing the end materials with rainwater. No. 500 is sprayed onto the soil while 501 is sprayed onto plants (Sattler 1992).

Preparations 502 to 508 are made from the following plant substances, respectively: yarrow blossoms, chamomile blossoms, stinging nettle, oak bark, dandelion flowers, valerian flowers, and horsetail. Each preparation is made in a very specific way. For example, No. 502 is made from yarrow flowers that are put in the bladder of a red deer stag, suspended in the sun throughout the summer and buried in the ground during the winter. It is then added to a compost pile, along with some of the other preparations, to aid the composting process, resulting in Biodynamic compost. Certain animal parts are used in the other preparations, such as bovine mesentery, bovine intestines, and domestic animal skulls. For more detailed descriptions of Steiner's preparations and their uses see Sattler 1992. Sattler emphasized in his book that little or no result can be expected if a preparation is used on its own. It needs to be used in concert with all of the other Biodynamic principles, processes and preparations.

Rhythms are also an integral part of Biodynamic farming. It is felt that biological rhythms are connected in some way to cosmic rhythms. For example, Steiner felt that sun spot activity, moon rhythms, and the zodiac all have significant effects on the growth and health of plants. Space does not allow a detailed explanation here but see Sattler's book for more details.

Definition of Sustainable Farming

In 1987 the World Commission on Environmental Development published a definition of sustainable development that is definition some use when discussing sustainable farming. The report stated that sustainable development is "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Most definitions of sustainable farming are based on the three E's of sustainability, farming that is economically viable, environmentally sound, and socially equitable. It focuses on all aspects of farming, including crop yield and quality, the management of soil, water and nutrients, air quality, energy use, management of non-farmed areas, biodiversity, packing and shipping, family, employees and the surrounding community.

I think that visualizing sustainable farming as a continuum, from less sustainable on the one hand to more sustainable on the other, is very helpful when trying to understand the sustainability paradigm. If an undisturbed natural system is the benchmark for complete sustainability one must realize that no farmer will be completely sustainable because the act of farming disturbs the natural system no matter how sustainable are the practices. Therefore, the goal of sustainable farming is continual improvement, in other words moving along the continuum toward a higher level of sustainability.

When comparing organic and biodynamic farming with conventional and sustainable farming it is important to remember that organic and biodynamic farming were established and codified in the 1920's – 1940's. The practices they espouse are ones that addressed the concerns of the day; soil health and the risks of using synthetic fertilizers and pesticides. Present day concerns related for farming are the use of water, energy, its impacts on biodiversity, and social equity. So the practices promoted by these two paradigms address these issues, while organic and biodynamic practices do not because they were codified a long time ago. I often get asked if growers farming sustainably are transitioning to organic farming. I always answer 'not necessarily' because organic certification does not address energy, water, biodiversity or social equity.

Comparing Organic, Biodynamic, Conventional and Sustainable Farming

When comparing the four farming paradigms it is important to distinguish between farming concepts and practices. The practices one uses to grow crops are chosen to bring one's concepts into reality. The four farming paradigms share in some concepts. All view the soil as the foundation to a productive farm. I believe that they all view the production field as a part of a larger system and understanding how that system works is critical to be a successful farmer. However, each paradigm differs as to their belief in how the larger system functions and the level of importance each system component plays. They all have to figure out how to be profitable. However, they differ on how costs are categorized and in some of their value propositions.

If one looks at some of the practices promoted or required by each paradigm their differences are quite clear. Table 1 attempts to provide a brief summary of the characteristics of each farming paradigm. However, in many ways this approach does not do justice in comparing these complex farming paradigms.

	Organic	Biodynamic	Conventional	Sustainable
Certification Standards	One set	One set	None	Many sets
Synthetic materials allowed	No	No	Yes	Yes
Principles	Ecological	Ecological & Cosmic	Ecological	Ecological
Animals required	No	Yes	No	No
Preparations required	No	Yes	No	No
Energy Use	No	No	Yes	Yes
Water Use & Quality	No	No	Yes	Yes
Social Equity	No	No	Yes	Yes
GHG Production	No	No	Yes	Yes

Table 1. Side by Side Comparison of Farming Characteristics

My view of sustainable farming is a very broad one and therefore visualize it as an umbrella under which all other farming paradigms can be placed. I can do this, in part, because there is no national consensus on one set of sustainable farming practice standards. Organic, conventional and Biodynamic farming all share some common concepts and practices. They also differ in some concepts and practices. I know some would argue that there are certain organic and Biodynamic practices that are not sustainable, particularly related to fuel consumption and/or labor practices. However, this is assuming a threshold has been established by someone to say what is and is not acceptable. At this point in time, I do not think it is helpful to discuss farming paradigms in this manner.

Concluding Remarks

I believe that the sustainable farming paradigm is here to stay. From 2011 to 2015 the percentage of S&P 500 Companies that are doing sustainability reporting went from 20% to 81%. The sustainable farming landscape will continue to change. For example, I am seeing the term ‘regenerative agriculture’ used more and more as a name for the paradigm. There is every indication that the agri-food supply chain is going increase its demands on growers to report on how they are growing their crops. Furthermore, it is likely that verification of the use of practices and metrics use will become more common. Most sustainable farming initiatives and certification programs have been practice-based, but I see an increase in the use of metrics to measure important inputs like water, pesticides, nutrients and energy and important outcomes like greenhouse gas production. Regulatory compliance will continue to increase but at a slower pace than supply chain compliance.

There is a lot happening in the sustainable farming arena and the challenge is what to do about it. I believe that trade associations can play an important role in helping their members meet these challenges in a pro-active and business-smart way. The sustainable farming programs developed by the Lodi Winegrape Commission, California Sustainable Winegrowing Alliance, and the Almond Board of California are great examples. As an individual, your goals for the future will determine how you address sustainable farming and what type of program will achieve them. If you have not thought about your goals for a while, take some time to do so. As Yogi Berra once said 'If you don't know where you are going, you may end up some place else'.

Literature Cited

American Society of Agronomy. 1989. Decisions reached on sustainable agriculture. Agron News January. p 15.

Childs, G. 1995. *Rudolf Steiner: His life and work.* Anthroposophy Press, N.Y.

Francis, C. A., G. Youngberg. 1990. Sustainable agriculture—An overview. *In:* Sustainable agriculture in temperate zones. Francis, C. A., C. B. Flora and L. D. King, eds. John Wiley & Sons, N.Y. pp. 1-12.

Koepf, H. H. 1976. *Bio-dynamic agriculture: An introduction.* Anthroposophic Press. NY. 429pp.

National Organic Standards Board (NOSB). 2007. Policy and procedures manual. Nat. Org. Stand. Board, Washington, DC. 67pp.

Parayil, G. 2003. Mapping technological trajectories of the Green Revolution and the gene revolution from modernization to globalization. Research Policy 32(6):971-990.

Rodale, R. 1973. The basics of organic farming. Crops and Soils 26(3):5-7,30.

Sattler, F. 1992. *Biodynamic farming practice.* Bio-Dynamic Agricultural Assoc. 333pp

UC-SAREP. 2008. University of California Sustainable Agriculture Research and Education Program Website: http://www.sarep.ucdavis.edu

World Commission on Environment and Development. 1987. Our Common Future. Oxford University Press. 398pp.

Resource sustainability in organic agriculture: Public understanding

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Organic farming can be examined from several perspectives, first as a 20th c. historical movement and developing philosophy around the practice of agriculture, secondarily as a legal definition codified in Federal Regulations administered by The National Organic Program (NOP) within the USDA's Agricultural Marketing Service, adherence to which confers the legal right to market food products as Certified Organic. Birthed in the early 20th c. in reaction to industrializing agriculture's substitution of mineral salts and Haber-Bosch synthetic ammonia for biological mineralization of soil organic matter (SOM), the organic movement's early luminaries included Austria's Rudolph Steiner, Britain's Sir Albert Howard and in this country, J.I. Rodale of Rodale Press.

In broad definition, organic agriculture is simultaneously prescriptive by its reliance on natural systems for plant nutrition, pest, and disease control, as well as proscriptive by its rejection of synthetic and toxic inputs. Widespread scientific illiteracy focuses public perceptions on the latter, yoking organic with a negative definition unduly emphasizing what it eschews vs. the holy grail it pursues, a self-perpetuating agriculture that does not degrade the natural resource base on which its productivity depends. There is no validity to claims that organic practice in its current NOP-defined iteration is "sustainable", nor any evidence that the short-lived experiment we call agriculture can itself be sustained into an indefinite future, notwithstanding its immense current productivity. Based on some 30 years as a Certified Organic farmer, I must admit to several internal contradictions in NOP-allowed practice. As a matter of practicality, animal or plant-derived manures and composts may be obtained from conventional sources, and most are when California's high-yield organic vegetable growers commonly apply 10 tons of organic amendments per acre to produce a crop. It is rarely mentioned that animal diets and plants that comprise compost feedstocks are largely grown with Haber-Bosch nitrogen, prohibited as a direct input to organic systems but somehow sanctified once routed through a cow's rumen or a plant's lifecycle. So, why not just pour sack nitrogen into organic systems?

In addition to the well-observed fact that plants receiving a nitrogen bolus can become over-stimulated and more prone to pest and disease outbreaks, freely available nitrogen's complex effects on minimally understood but critical functions of soil and plant microbial communities have become a focus of research in universities across the globe, paralleling microbiome research in human health and medicine. University of Florida phytopathologist Ariena H. C. van Bruggen, amongst others, has shown that organic soil amendments stimulate greater microbial community diversity and activity, internal nutrient cycling and resilience to disturbance, services that contribute to the effective functioning of plant immune systems. She further points out that common agricultural practices, such as, addition of any nutrient source, tillage and drying-rewetting create significant soil biological disturbances from which organically managed soils are more buffered and recover more quickly.

Although New Mexico State University molecular biologist David C. Johnson contends “a healthy soil microbiome is such an aggressive nutrient cycling system that nothing escapes”, California’s organic farmers’ “pay it forward” approach to fertility might encounter unique difficulties in satisfying the Irrigated Lands Regulatory Program and its nutrient management planning requirements. Though a ton of mature compost contains a significant nutrient storehouse, its nitrogen has been sequestered into living and dead microbe anatomies. Biological farmers and agronomists estimate soil-applied composts convert 10% to 20% of their insoluble organic nitrogen into plant-available form the first year, followed by 5% to 10% returns for years thereafter. Soil-applied compost functions like an interest-bearing savings account. Complexed compost nitrogen slowly mineralizes through secondary microbial degradation of organic matter, as well as nutrient release from intricate predator-prey soil food web interactions. The layering effect of multiple-year compost applications, each with a differing estimated release curve, may make it challenging to satisfy regulators’ concerns over irresponsible fertilization. Insufficient field data has been collected to prove or disprove David C. Johnson’s hypothesis that nutrients are well-sequestered in biologically intensive systems.

Increased regulatory pressure may drive organic farmers from a hallowed ‘feed the soil’ maxim towards input substitution schemes that mirror conventional farming’s ‘feed the plant’ approach, embracing such inputs as thermally sterilized chicken manure pellets that legally guarantee a nitrogen analysis, a trend already popular with large organic producers hypersensitive to food safety issues. Ironically, pathologist van Bruggen contends “more oligotrophic soil systems (meaning the reduction of mineral nitrogen, soluble carbon compounds and available phosphorus but not organic matter content) will not only show lower nutrient losses due to emission and leaching, but also have the potential to decrease [human] pathogen persistence.” Concerns that such oligotrophic agroecosystems fail to sponsor adequate, continuous, and /or timely fertility for production agriculture systems proved unfounded in T&D Willey Farms’ case on 75 acres of Madera, Ca. fine sandy loam (Storie Index 100) over 20 years of intensive, year-round vegetable production. Average 15 tons per acre compost applications (80% Plant Material / 20% Dairy Manure) supported a high rotational diversity vegetable system averaging 1.5 crops per year, in which optimum macro and micronutrient levels were maintained with minimal supplementation to produce consistent $40,000 per acre annual gross revenues. Nitrogen supplements to this system from fish emulsion never exceeded 10 total units per acre. Although an initial average 7.25 pH sometimes ranged above 8 over subsequent years, micronutrient assimilation was excellent except for Mn. Fe, very minimally present in our soil, was amazingly plant available, a phenomenon I attribute to high soil microbiome activity featuring species known to mediate micronutrient uptake.

Foundational to T&D Willey Farms’ soil management program was William Albrecht’s system of major cation balance in which Ca (75 – 80% CEC) reigns “King”, followed by Mg (10 – 15% CEC), Na (0 – 2% CEC), and K (5 – 7% CEC). Though our compost applications represented an annual ¼% contribution to SOM, which averaged 1.5 – 2% initially (4 yrs. fallow and undisturbed), 20 years later SOM averages remained the same. However, observed water holding capacity increased substantially over the two decades, as did CEC, nearly twofold from 8 to 15, suggesting some qualitative change in SOM. Flatline SOM levels reveal another inconsistency in standard organic practice shared with many but not all conventional farmers, heavy reliance on tillage. Lacking access to pre-emergent or effective contact herbicides, organic farmers till and cultivate more intensively than their conventional brethren, oxidizing SOM at high rates, particularly in semi-arid environments. Until organic systems somehow learn to embrace no-till, a unique challenge in vegetable production, we'll need to shovel lots of "coal" into the firebox, possibly outstripping compost feedstock resources should acreage greatly expand. Let's confront a related T&D Willey shortcoming; carbon can be grown *in situ* employing cover crops, a common organic practice that my late agronomist friend, Ralph Jergens, strongly encouraged. This requires time and space, which our four-season production system held at a premium, committed as we were to employing fifty fulltime, year-round field hands on 75 acres. I long regarded importing carbon in compost from elsewhere as essentially equivalent to cover cropping, an error I've only recently come to appreciate.

Some half-dozen years ago, fifteen world-eminent soil scientists gathered in an ancient Swiss Carthusian monastery over three days to share the newest discoveries in their field. Controversy ensued when several declared the long-venerated 'god' humus was dead; those putative large compound molecules, highly resistant to microbial assault, a focus of soil research for a century or more, were revealed as either rare or absent in detailed molecular and microscopic examination of soil. Equally astonishing was the disclosure that plant sugars exuded from plant roots into soil, believed to be among the shortest-lived of organic materials, can and do persist for decades. In a second *Nature* (2015) publication on this topic following their history-making Swiss conference, Lehmann & Kleber further debunk 'humification' theories, categorically stating that "soil organic matter is a continuum of progressively decomposing organic compounds", adding that "soils will be "healthy" and fertile when we ensure constant production of reactive, assimilable, labile carbon."

The few farmers accomplishing this successfully, steadily building soil carbon stores while producing economic crops, appear to be a progressive group of Midwest and East Coast no-tillers. Beyond soil non-disturbance, what characterizes these conventional farmers' practice are continuous soil cover, expanded rotations, seeding cover crop blends of 10 – 15 species, and rotational, intensive ruminant grazing. This system's most adept practitioners report having reduced chemical inputs for fertility, pest, disease and weed control by some 80% while maintaining or increasing economic productivity. The movement's heralded 'poster boy', North Dakota's Gabe Brown, increased his farm's SOM from 1% to more than 6% over the same 20 years my composted soil's SOM remained flat. Multiple cover crop species secrete an enormous range of phytochemical compounds (which can account for 30 – 40% of a plant's total fixed carbon) into the rhizosphere where these stimulate and amplify different members or communities within a soil's microbiome, a powerful effect lost to California organic cover croppers who commonly grow simple rye – vetch or rye – bell bean blends.

At NMSU, David Johnson's Biologically Enhanced Agricultural Management (BEAM) research inoculated low fertility, agricultural desert soil with a mere few hundred pounds per acre of fungal-dominant compost, which (with no additional fertilization) stimulated high biomass yields of multispecies winter and single species cover crops. Johnson found that increasing the fungal to bacterial biomass ratio (F:B) from 0.04 (control) to 1.0 and beyond was the principle factor correlating to high biomass production and the partitioning of greater amounts of photosynthetic carbon to soil vs. that allocated to plant biomass and microbial respiration. Though he has not yet integrated economic crops or harvest exports into his system, BEAM's extraordinary productivity suggests that agroecosystems can sponsor greater internal fertility, relying on fewer outside inputs, while significantly contributing to the reduction of atmospheric carbon. Lawrence Berkeley National Laboratory's DNA Microarray for Rapid Profiling of Microbial Populations, also called PhyloChip and similar technologies are propelling a revolution in soil microbiome research that will yield rich dividends for agriculture. Though some 35,000 species of soil bacteria can be differentiated, few have been named and classified; more mysterious yet are the functional roles these play in an immensely complex soil food web. Unravelling enough of soil's biological Gordian Knot might key our entry into sustainable agriculture, a long walk on which the organic movement has choreographed a few initial baby steps. Van Bruggen believes barriers must be overcome to engaging in systems-level interdisciplinary research on experimental plots and commercial farms that will provide results relevant to the development of ecologically sustainable agricultural systems.

Literature Cited

Ariena H. C. van Bruggen, Alexander M. Semenov, Anne D. van Diepeningen, Oscar J. de Vos, Wim J. Blok. Plant disease epidemiology: facing challenges of the 21st Century. 2006. pp 105-122.

E Franz, AHC van Bruggen. Ecology of E. coli O157: H7 and Salmonella enterica in the primary vegetable production chain. Critical reviews in microbiology 34 (3-4), 143-161.

AHC van Bruggen, A Gamliel, MR Finckh. Plant disease management in organic farming systems. Pest management science 72 (1), 30-44. https://www.researchgate.net/profile/Maria_Finckh/publication/281116015_Plant_Disesaes_and_Their_Managment_in_Organic_Agriculture/links/576cfe0408aedab13b862e35.pdf

Soils hidden secrets. http://www.ess.uci.edu/news/soil201201

Persistence of soil organic matter as an ecosystem property. Michael W. I. Schmidt1 *, Margaret S. Torn2,3*, Samuel Abiven1 , Thorsten Dittmar4,5, Georg Guggenberger6 , Ivan A. Janssens7 , Markus Kleber8 , Ingrid Ko¨gel-Knabner9 , Johannes Lehmann10, David A. C. Manning11, Paolo Nannipieri12, Daniel P. Rasse13, Steve Weiner14 & Susan E. Trumbore15. *Nature* **478** 49–56 (06 October 2011) http://www.css.cornell.edu/faculty/lehmann/pictures/publ/Nature%20478,%2049-56,%202011%20Schmidt.pdf

The contentious nature of soil organic matter. 2015. Johannes Lehmann & Markus Kleber. Nature 528(7580) · November 2015. DOI: 10.1038/nature16069. http://www.nature.com/nature/journal/vaop/ncurrent/pdf/nature16069.pdf

David Johnson, Joe Ellington, Wesley Eaton. Development of soil microbial communities for promoting sustainability in agriculture and a global carbon fix.
file:///C:/Users/Tom/Downloads/789v1.pdf

AHC Van Bruggen. 1995.Plant disease severity in high-input compared to reduced-input and organic farming systems. Plant disease 79 (10), 976-984.
http://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1995Articles/PlantDisease79n10_976.PDF

Pesticide Residues Issues in California: Is Our Food Safe?

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Public concern regarding pesticide residues continues to be a major factor influencing consumer attitudes, purchasing behavior, marketing, and regulation. While it is clear that California consumers are routinely exposed to residues of pesticides in the diet, the levels of exposure to such pesticides is typically several orders of magnitude below levels of health concern. Consumers may reduce, but not eliminate, their exposure to pesticides in the diet through purchase of organic foods. Evidence suggests that consumers following the Environmental Working Group's "Dirty Dozen" recommendations may actually be consuming fewer fruits and vegetables in their diet than those who don't. The best advice for consumers is to eat large amounts of fruits, vegetables, and whole grains, regardless of whether the foods are conventional or organic.

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Session # 5

Agricultural Water Management

Session Chairs:

Robert Hutmacher & Dan Munk

Sustainable groundwater management: on-farm vs. dedicated storage issues

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As California landowners prepare to form groundwater management plans under the new 2014 groundwater legislation, the Sustainable Groundwater Management Act (SGMA), it becomes increasingly important to develop new recharge technologies, which can directly utilize irrigated agriculture and excess water to replenish groundwater. In California, groundwater is often used independently or in tandem with surface water for irrigation and urban supply during dry periods when surface water flows are limited. As a result, conjunctive use, the practice of coordinating the use of surface and groundwater resources such that the benefits exceed the use of either resource independently (Sahuquillo and Lluria 2005), has emerged as an important water management strategy across California. Aquifer storage and recovery (ASR) and Managed Aquifer Recharge (MAR) are two conjunctive use strategies utilized in California.

MAR can use several methods, including injection wells, aquifer storage and recovery (ASR, with injection and extraction through the same wells), vadose zone dry wells, and infiltration basins (Russo et al. 2014). While injection wells and ASR may offer advantages such as limited land requirements, they can be technically challenging to design, have high energy and water quality requirements, and require creation and maintenance of conveyance and pumping systems (Bouwer 2002). In contrast, designated infiltration basins may require less engineering and result in lower operating costs than injection wells or ASR systems. However, spreading basins often require relatively large land areas purchased at high costs, bear the risk of recharging contaminated water or degrading groundwater geochemistry (Cey et al. 2008), and the challenge of identifying locations having surface and subsurface conditions amenable to infiltration.

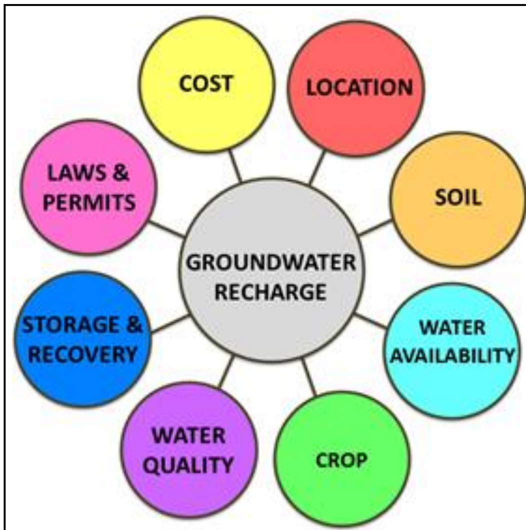

Figure 1: Factors influencing the feasibility, risks and benefits of agricultural groundwater banking

In recent years, agricultural groundwater banking (AGB) has emerged as a promising groundwater replenishment opportunity in California (Bachand et al. 2014, Harter and Dahlke, 2014); AGB is a form of MAR where farmland is flooded during the winter using surface water in order to recharge the underlying groundwater for later use when surface water supplies are limited. Using farmland for recharge and groundwater banking potentially addresses several climate-change-induced water management concerns within the state and provides opportunities for long-term water security in California. In the past California's water supply has relied on surface water reservoirs and the mountain snowpack to store water in the winter for use during the summer months. California's surface water reservoirs have the capacity to store nearly 50% of the average annual statewide runoff (about 42.8 million acre-feet) but provide limited carry over storage to supply water during prolonged drought (Hanak et al. 2011, Mirchi et al. 2013). With the predicted loss of the snowpack (25-40%, (Mote et al. 2005)), CA is losing its capacity to store about one third of its annual surface water supply. Unfortunately, reservoirs do not provide enough storage capacity or, because of federal laws cannot be operated to capture all the runoff from winter rainstorms, which means that we have to find new ways to capture and store water from winter rainstorms. Over the past century, CA has also severely overdrafted its groundwater reserves. Cumulative groundwater depletion in the Central Valley has reached about 81 million acre-feet since the 1960s. The state's depleted groundwater aquifers provide more than twice the storage capacity of surface water reservoirs, which could be used to capture and recharge excess surface water during wet years for use during drought years.

California also has a unique climate in that most of California's total annual precipitation derives from a few large storms over 5-15 total days, including landfalling atmospheric rivers, which contribute 20-50% of the state's precipitation (Dettinger et al. 2011). In order to capture runoff from these storms, large spreading areas are needed. California has over 8 million acres of irrigated farmland that could serve as spreading grounds for groundwater replenishment. Using farmland would also have the advantage that that the existing irrigation infrastructure could be used to move water from streams and reservoirs to fields for recharge. However, challenges and concerns remain regarding the availability of surface water for groundwater recharge, the effect that winter, on-farm flood flow capture could have on perennial cropping systems such as alfalfa, tree and vine crops and groundwater quality, and the long-term fate and storage of the banked water in groundwater aquifers (Fig. 1).

The study presented here considers the availability of excess streamflow (e.g., the magnitude, frequency, timing, and duration of winter flood flows) for AGB and the risks and benefits associated with using alfalfa fields as spreading grounds for AGB within California's Central Valley.

The availability of surface water for winter (Nov. – Apr.) AGB was estimated based on daily streamflow records for 93 stream gauges within the Central Valley, CA. Analysis focused on high-magnitude (above 90th percentile) flows because most lower flows are likely legally allocated in CA. Results based on more than 50 years of data indicate that in an average year approximately 2.55 million acre feet of high-magnitude flow is exported from the entire Central Valley to the Sacramento-San Joaquin Delta often at times when demand quantities and water quality requirements of the Delta are fulfilled. High-magnitude flow occurs, on average, during 7 and 4.7 out of 10 years in the Sacramento River and the San Joaquin Tulare Basin, respectively, from just a few storm events (5 – 7 1-day peak events) lasting for 25-30 days between November and April. During wet years, the Sacramento River Basin and San Joaquin River basin could provide about 2.66 and 1.36 million acre-feet of water for AGB from flows above the 90th percentile. The results suggest that there is sufficient surface water physically available, but currently underutilized, to mitigate long-term groundwater overdraft of 1.5-2 million acre-feet per year in the Central Valley.

Wintertime on-farm recharge experiments were conducted on old (>5-year) alfalfa stands in Davis and the Scott Valley (Siskiyou County), where variable amounts of winter water (4-28ft for alfalfa) and different water application timings were tested. At the 15-acre Scott Valley site a total of 135 AF and 107 AF of water were recharged during the winters of 2015 and 2016, respectively. Alfalfa yield data collected indicates that pulsed application of winter water on dormant alfalfa did not conclusively result in a significant decline in yield suggesting that the effect of winter flooding on dormant alfalfa is potentially small. Results from our two on-farm experiments indicate that an astoundingly large fraction of the applied winter water percolated past the root zone and was moving towards the groundwater table. From the tested winter water application amounts, which ranged between 4ft and 6.7ft at the Davis site and between 2.6ft and 26ft at the Scott Valley site over 90% of the applied water went to deep percolation. Depending on antecendent moisture conditions and the water storage capacity of the soil most events resulted in small losses of the applied winter water to soil storage (e.g. to bring the soil water content to field capacity). At both sites the collected soil moisture data indicated rapid drainage of the soil profile following the end of irrigation events. Saturated conditions in the soil profile prevailed at most for up to 12 hours after water applications ceased at the Davis site and for up to 4 hours at the Scott Valley site indicating that water logging of the soil profile and the root zone was minimal. While the winter water application timing had little effect on the total deep percolation amounts, it played a vital role for the root zone water balance at the onset of the growing season. In the drought year of 2014/2015, test plots, which received winter water applications for recharge late in the winter season (e.g. March/April) showed clearly a higher plant available water content at the onset of the growing season (1-2 inches) than the control plots. Together these results highlight the opportunity and potential benefits for growers and water districts to implement AGB as part of the sustainable groundwater management plans.

References

Bachand, P.A.M., Roy, S.B., Choperena, J., Cameron, D., and Horwath, W.R., 2014, Implications of using On-Farm Flood Flow Capture to recharge groundwater and mitigate flood risks along the Kings River, CA. Environmental Science & Technology 48 (23), 13601-13609.

Bouwer, H. 2002. Artificial recharge of groundwater: Hydrogeology and engineering. Hydrogeology Journal 10: 121–142. DOI: 10.1007/s10040-001-0182-4. http://www.springerlink.com/index/U0R3XTXNNFQM4P6Y.pdf.

Cey, B.D., B.G. Hudson, J.E. Moran, and B.R. Scanlon. 2008. Impact of artificial recharge on dissolved noble gases in groundwater in California. Environmental Science & Technology 42, no. 4: 1017–1023.

Hanak, E., Lund, J., Dinar, A., Gray, B., Howitt, R., Mount, J., Moyle, P. and Thompson, B., 2011. Managing California’s Water: From Conflict to Reconciliation. Public Policy Institute of California.

Harter, T. and Dahlke, H., 2014. Out of sight but not out of mind: California refocuses on groundwater. California Agriculture, 68(3), pp.54-55.

Mirchi, A., Madani, K., Roos, M. and Watkins, D.W., 2013. Climate change impacts on California’s water resources. In Drought in Arid and Semi-Arid Regions (pp. 301-319). Springer Netherlands.

Mote, P.W., Hamlet, A.F., Clark, M.P. and Lettenmaier, D.P., 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society, 86(1), p.39. Dettinger, M., 2011. Climate change, atmospheric rivers, and floods in California–a multimodel analysis of storm frequency and magnitude changes. Journal of the American Water Resources Association, 47(3), pp.514-523.

Russo, T.A., Fisher, A.T. and Lockwood, B.S., 2015. Assessment of managed aquifer recharge site suitability using a GIS and modeling. Groundwater, 53(3), pp.389-400.

Sahuquillo, A., and M. Lluria (2005). Conjunctive Use as Potential Solution for Stressed Aquifers: Social Constraints. Intensive Use of Groundwater: Challenges and Opportunities. A A Balkema Publishers.

Intentional Agricultural Recharge Suitability

Joel Kimmelshue, Land IQ

American Society of Agronomy

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Session # 6

Soil Biology: Understanding Management Options and Potential Benefits

Session Chairs:

Karen Lowell & Margaret Ellis

Soil Health Lessons from Long-term, Organic Vegetable Research

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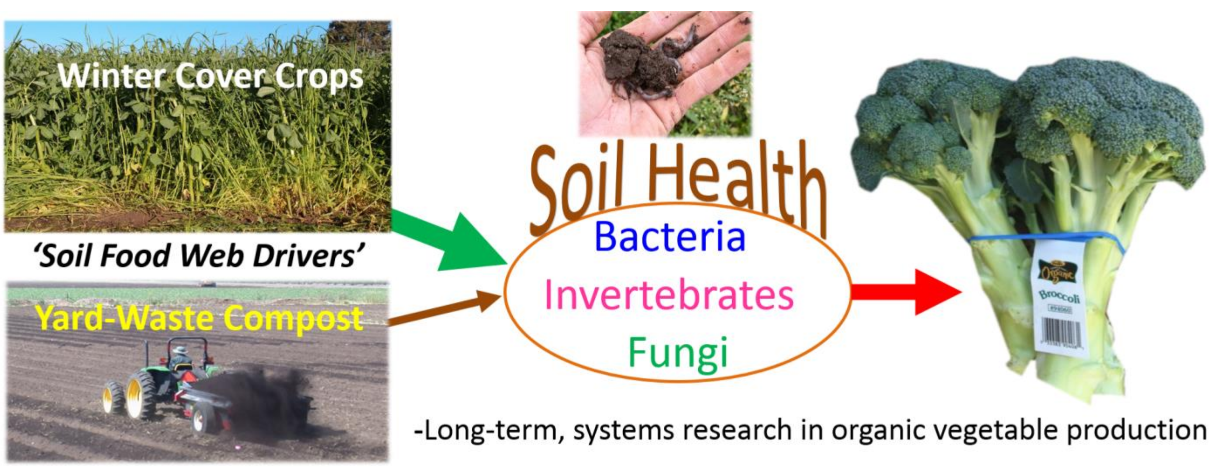
Soil health, also known as soil quality, depends on a complex food web of interacting soil organisms including bacteria, fungi, protozoa, nematodes, arthropods and earth worms that rely on energy-rich, plant residue. In agricultural systems these residues may come from crop residue, compost or cover crops. This presentation will focus on soil health changes during 8 years of commercial-scale organic vegetable production in an exciting, on-going, and relatively long-term study called the Salinas Organic Cropping Systems (SOCS). It will focus on five management systems that differed in yard-waste compost inputs (none versus 15.2 Mg/hectare/Year; 6.8 ton/acre/year, oven-dry basis), winter cover crop frequency (annually or every 4th year), and cover crop type (legume-rye, mustard, or rye). All systems had the same levels of irrigation, tillage, and supplemental organic fertilizer inputs during the production of spinach, lettuce and broccoli. The presentation will illustrate soil health changes during 8 years of vegetable production using data various soil microbial indicators and (2) highlight the value of confidence intervals and raw data to visually understand experimental results without the use of complex statistics. This soil health results from the SOCS experiment indicate that carbon inputs from cover crops are the most important driver in the soil food web in intensive vegetable systems (see graphic below). This research has important implications for organic and conventional production systems in the Salinas Valley and beyond.



Useful Links:
-the presentation will draw from our nematode paper (click to download), and recent analysis focused soil microbial biomass and community structure (Brennan & Acosta-Martinez. 2017, *In Press*, Cover cropping frequency is the main driver of soil microbial changes during six years of organic vegetable production. Soil Biology & Biochemistry. Please email Eric.Brennan@ars.usda.gov for a copy of this new paper).

-Eric's research publications: www.researchgate.net/profile/Eric_Brennan/publications
-Eric's videos: www.youtube.com/user/EricBrennanOrganic

Impact of Biological Amendments on *Agrobacterium tumefaciens* survival in soil

Daniel Kluepfel, Research Leader, USDA-ARS Crops Pathology and Genetics Research Unit, Davis, CA.

Evaluation of Four Commercial Composts on Strawberry Plant Productivity and Soil Characteristics in California

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Composts can have beneficial effects on strawberry production and these benefits can be dependent on the type of compost used. Four commercial composts were evaluated: cow manure, spent mushroom, yard trimmings, and vermicompost. The nutrient composition, abundance of fungi and bacteria, and microbial activity were determined. Five field trials assessed effects on plant growth, root development, soil microbial activity, nutrient availability, and yield during one growing season.

Manure and mushroom compost significantly increased soil electrical conductivity levels to 9.9 ± 1.7 dS/m and 7.3 ± 0.8 dS/m, respectively. Manure, yard trimmings, and mushroom composts shifted soil pH toward optimal levels for up to 7 months. Mushroom compost had the greatest effect on soil nitrate, which was up to 32 mg/kg of soil higher than non-amended soil. Significant effects on yield were more likely to occur where environmental conditions and management practices were less than optimal or compost was not routinely added. Compost also suppressed activity by *Pythium ultimum*. Several factors important to plant production were significantly affected by compost: soil salinity, plant establishment, soil nitrate, production curves, soil microbial activity, and soil pH.

Reference

Lloyd, M., D. Kluepfel, and T.R. Gordon. 2016. Evaluation of Four Commercial Compost on Strawberry Plant Productivity and Soil Characteristics in California. *International Journal of Fruit Science.* 16:84-104.

See also YouTube Video on the research: https://www.youtube.com/watch?v=vX5j1p9z4YM

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Session #7

Measuring and managing variability

Session Chairs:

Andre Biscaro & Stan Grant

Precision Nutrient Management in California Orchards

Patrick Brown – UC Davis, Dept. Plant Science

Variable Rate Drip Irrigation for Vineyards

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Abstract

Vineyard spatial heterogeneity in soil properties causes variability in vine performance. Ideally, irrigation should be applied differentially throughout the vineyard in order to compensate for soil variation and optimize both fruit yield and quality. A variable rate drip irrigation (VRDI) system was implemented in early 2013 in a 10-acre area inside a drip-irrigated Cabernet Sauvignon vineyard measuring 32 total acres. The VRDI area contained the full range of yields present in the vineyard (based on the 2012 yield map) and was split into 140 15x15-meter irrigation zones which were watered independently during three seasons by drip irrigation with weekly schedules calculated through an energy balance approach using Landsat and local weather data. Irrigation during 2013 and 2015 was scheduled with the objective of decreasing spatial variability while maintaining high yields, whereas in 2014 to more aggressively increase yield and canopy development in low vigor/yield zones. NDVI was derived from Landsat data or from airborne images captured after veraison and yield was mapped from yield monitor data collected at harvest. Non-spatial variability of both yield and NDVI in the VRDI section decreased significantly in 2013 and 2015 and moderately in 2014 compared to an adjacent 10-acre section of conventionally drip irrigated (CDI) vineyard. Compared to CDI, VRDI also decreased spatial dependency and structure in 2013 and 2015 as indicated by the mean correlation distance (MCD) and the Cambardella index (CmbI). Yield and water use efficiency were higher in VRDI than CDI in all three years (10% and 12% on average respectively).

Introduction

Due to soil variability, within-vineyard yield differences of up to 10-fold are common (Bramley and Lamb 2003). Similar differences exist in canopy surface and density, resulting in variable vine water demand. Irrigation technology has not yet developed a differential system for permanent crops. Approaches to differential irrigation have been implemented as sensor-triggered systems in greenhouses (Lichtenberg et al. 2013), small farms (Kamel et al. 2012) or in center pivot-irrigated grain crops (Patil and Al-Gaadi 2012). Vineyards have been divided in a small number of management zones and irrigated accordingly in Australia (McClymont et al. 2012; Proffitt and Pearce 2004) and Spain (Bellvert et al. 2012; Martínez-Casasnovas et al. 2009). Likewise, in some drip-irrigated California vineyards variable watering rates are empirically achieved by increasing or decreasing the number of irrigation tubing or emitters per vine. However, the rates achieved with zonal irrigation are hard to modify once in place and in some cases the length and frequency of irrigation periods cannot be controlled independently for each zone because all the emitters are connected to the same circuit and a single pump.

The main objective of the study described herein was to develop a proof-of-concept variable rate irrigation (VRDI) system prototype, operate it using an energy balance model based on remotely sensed data (Landsat) and differentially deliver water to 140 equally sized irrigation zones to manipulate vine growth and yield. The system was conceived, designed and installed in the field in early 2013 and operated for the entire 2013, 2014 and 2015 growing seasons. The basic design and functioning principles of the system as well as its effect on vineyard variability, vine yield and water use efficiency during the three years of operation are described below.

Materials and methods

A highly variable, hand-pruned, drip-irrigated, 17-year old Cabernet Sauvignon vineyard, for which yield had previously been mapped during the 2012 harvest, was selected for this study. The 32-acre block is located north of Lodi, California (38°21'13.60"N/121°15'1.80"W; elevation 21 meters). Local average precipitation is 500 mm occurring mostly during winter. The VRDI study was set up in a 10-acre rectangular section that included the full range of yields seen in the rest of the block according to the 2012 yield map (Figure 1). The perimeter of the VRDI section was aligned with the 30 x 30 m pixels of the Landsat image outputs, and each pixel outline was further divided into four 15 x 15 m quadrants, each one defining an independent irrigation zone. This delineation resulted in a rectangle containing 140 irrigation zones, each containing 40 or 50 vines. A second 10-acre grid, containing 140 15 x 15 m zones with similar high and low yields, was digitally setup adjacent to the south edge of the VRDI area to extract "control" spatial data and was denominated conventional drip irrigation (CDI).

The VRDI prototype consisted of a variable flow submersible pump, underground pipes, water valves, flow meters, and a large panel holding several enclosures for power and electronics components as well as the central computer, an antenna and wireless modem for remote access and control of the system. Two plastic irrigation hoses (1.78 cm outside diameter) ran parallel to each other 15 cm apart on a vertical plane. The upper hose was fastened to a wire running along the vine row at a height of 60 cm. The lower hose ran along with the primary irrigation system hose and both were held by a second wire at a height of 45 cm. The two wires were fastened to the vine support stakes and both hoses were connected to each other through an "H" PVC assembly, in place every 10 vine spaces. Only the lower hose had emitters, two per vine. Independent irrigation of the each of the four or five 10-vine sections of each zone was achieved by a solenoid valve, a check valve, an enclosure containing an electronic control board as well as power and communication wiring. The primary irrigation system was kept in place as backup and for application of liquid fertilizers as needed. Irrigation of the 140 zones was controlled by a computer network with a single master coordinating operation communicating through a MODBUS-based protocol (Modbus.org 2006). Located on the panel with the master was a PC that was accessed remotely through a cellular link connection that allowed remote desktop operations, including uploading the weekly irrigation schedules.

VRDI irrigation was scheduled weekly using METRIC (Mapping evapotranspiration at high resolution and internalized calibration), a satellite-based image-processing model for calculating evapotranspiration (ET) as a residual of the surface energy balance (Allen et al. 2007). METRIC is applied using multispectral Landsat satellite imagery and weather data (CIMIS 2014). The primary output is actual evapotranspiration at the pixel scale. The following equation is applied to water each zone: ETc = (ETref)*(Kc)*(Km), where, ETc = crop evapotranspiration, ETref = reference crop evapotranspiration, Kc = crop coefficient (increases with canopy development), and Km = management factor. The 140 VRDI zones are derived from 35 Landsat pixel geolocations

(30 x 30 m), each one split into four, 15 x 15 m zones. This splitting is performed at the end of the above calculations by interpolating the final ETc values using Manifold System GIS software (v.8, Manifold Net Ltd., Carson City, NV, USA). Irrigations in 2013 and 2014 started on April 1. In 2013 all zones with 2012 yields below the 8.9 t ac^{-1} vineyard average were irrigated at Km = 1.2 for 4 weeks, followed by 0.5 the next 4 weeks and 0.7 the last 16 weeks. The zones which in 2012 were above average yield were irrigated as above except that no irrigation was applied during the first 4 weeks. In 2014 and 2015 all VRDI zones were irrigated as a function of crop stress index (calculated in METRIC) using variable Km values ranging from 0-0.7, 0.5-0.8 and 0.6 to 1.0 respectively during the same above periods. Zones with higher stress values (low vine vigor and yield) received more water. Proportionally higher Km values were applied to the low yield zones in 2014 than in 2013 and 2015. In 2015 Km was continuously adjusted based on vine vigor as indirectly estimated by the NDVI derived from Landsat data. The remaining vineyard was irrigated using the primary system at a uniform rate, with Km values at the discretion of the vineyard manager.

Airborne canopy reflectance high resolution data for calculating normalized vegetation indices (NDVI) was contracted from outside vendors. Additional lower resolution NDVI values were calculated from Landsat data on a weekly basis.

Yield was measured spatially at harvest (Bramley and Williams 2001) with yield monitors (ATV, Joslin, Australia) installed on several models of over-the-row trunk-shaking mechanical harvesters. Harvest data were cleaned-up with a script written in R Studio software (RStudio Inc., Boston, MA, USA) to convert mass flow units into tons per acre, eliminate outliers, and normalize harvesters. Data were then transferred into VESPER Version 1.62 (Minasny, McBratney, and Whelan 2005) for kriging to 3 x 3 m resolution.

Irrigation treatment effects were analyzed using the 3 x 3 m data or their average for each 15 x 15 m irrigation zone. Variogram parameters were obtained from VESPER and constrained to a range of 100 m to calculate spatial statistics for yield and NDVI. Qualitative spatial indices included the Cambardella index, CmbI (Cambardella et al. 1994), and the mean correlation distance, MCD (Han et al. 1994). Values of the CmbI were assessed as less than 25 indicating strong spatial dependency, 25-75 indicating moderate spatial dependency, and greater than 75 indicating weak spatial dependency. Conversely, higher MCD values were equated to greater spatial structure.

Results and discussion

Figure 2 shows the yield maps of VRDI and CDI for 2012 through 2015. Due to the natural variation in bud fruitfulness, whole-vineyard yield was high in 2012 and 2014, and low in 2013 and 2015, however yields under VRDI were on average 10% higher than under CDI in all three years of variable rate irrigation. The spatial distribution of high and low yielding areas did not change under CDI in all four years (Figure 2, lower panel). On the other hand, the VRDI strategies imposed during the three years of the study caused significant changes to spatial variability. Yield spatial variability decreased in 2013 and 2015. In 2014, by selectively increasing management factors in the low vigor/yield irrigation zones, VRDI reversed the relative spatial distribution of yield compared to 2012. Spatial structure varied according to these changes, being high in 2012 and 2014 and low in 2013 and 2015 for both yield and NDVI (Table 1). Remarkably, these yield differences were achieved without decreasing water use efficiency (WUE). In fact, WUE was on average higher in VRDI than CDI for all three years (Table 2). The shifts in yield due to VRDI can also be easily visualized in Figure 3.

The irrigation system used commercially available components and performed very well in general. The most common performance failure were solenoid valves not completely closing at the end of irrigation cycles, but this only amounted to up to 0.5% over-irrigation. These leaks were caused either by accumulation of debris at the valve, valve failure, or software-related communication issues between the control boxes and the valves.

Conclusions

A low-volume, VRDI prototype was successfully designed and deployed in a wine grape vineyard in California's San Joaquin Valley and irrigations were scheduled using an energy balance based model. Vine growth was effectively and immediately manipulated with variable rate irrigation. Yield was increased during the three seasons by an average of 10% with up to 17% gain in water use efficiency.

These VRDI first and second generation VRDI prototypes constitute new precision viticulture technology for the vineyard of the future, in which a modular, variable rate, flexible water delivery system is coupled with satellite-based irrigation for farming at the pixel level. This system can be used to irrigate each zone according to vine size without altering natural variability or to apply an irrigation management factor to low vigor areas in order to increase vine size and yield and decrease vineyard variability.

Acknowledgements

Levente Klein and Nigel Hinds, **IBM** TJ Watson Lab, Yorktown, NY
Alan Claassen and David Lew, **IBM** Systems and Technology Group, San Jose, CA
James Taylor, **New Castle University**, UK
Ernie & Jeff Dosio, **Pacific Agrilands**, Lodi, CA
Bernd Kleinlagel, **ATV**, Australia

Literature cited

ALLEN, R.G., TASUMI, M., and TREZZA, R. 2007. Satellite-based energy balance for Mapping evapotranspiration with internalized calibration (METRIC)-Model. Journal of Irrigation and Drainage Engineering ASCE 133: 380-394.

BELLVERT, J., MARSAL, J., MATA, M., and GIRONA, J. 2012. Identifying irrigation zones across a 7.5-ha 'Pinot noir' vineyard based on the variability of vine water status and multispectral images. Irrigation Science 30: 499-509.

BRAMLEY, R.G.V., and LAMB, D.W. 2003. Making sense of vineyard variability in Australia. *In* Proceedings of the IX Congreaso Latinoamericano de Viticultura y Enologia. pp. 35-54. Centro de Agricultura de Precision, Pontificia Universidad Catolica de Chile.

CDIMIS. 2014. California Irrigation Management Information System. *In* http://www.cimis.water.ca.gov/cimis/welcome.jsp.

KAMEL, N., EL-SHAFEI, A., SHARAF, S., and YOUSEF, D. 2012. A high-reliability database-supported modular precision irrigation system. *In* Proceedings of the 11th International Conference on Precision Agriculture (ICPA).

LICHTENBERG, E., MAJSZTRIK, J., and SAAVOSS, M. 2013. Profitability of sensor-based irrigation in greenhouse and nursery crops. HortTechnology 23: 770-774.

MARTÍNEZ-CASASNOVAS, J.A., VALLÉS BIGORDA, D., and RAMOS, M.C. 2009. Irrigation management zones for precision viticulture according to intra-field variability. *In* Proceedings of the EFITA (European Federation for Information Technology in Agriculture, Food and the Environment).

MCCLYMONT, L., GOODWIN, I., MAZZA, M., BAKER, N., LANYON, D.M., ZERIHUN, A., CHANDRA, S., and DOWNEY, M.O. 2012. Effect of site-specific irrigation management on grapevine yield and fruit quality attributes. Irrigation Science 30: 461-470.

MODBUS.ORG. 2006. MODBUS over Serial Line. Specification and Implementation Guide v 1.02. *In*, pp. 44. Modbus-IDA.ORG.

PATIL, V.C., and AL-GAADI, K.A. 2012. Precision fertigation in wheat for sustainable agriculture in Saudi Arabia. *In* Proceedings of the 11th International Conference on Precision Agriculture (ICPA).

PROFFITT, T., and PEARCE, B. 2004. Adding value to the wine business precisely: using precision viticulture technology in Margaret River. Australian and New Zealand Grapegrower and Winemaker: 40-44.

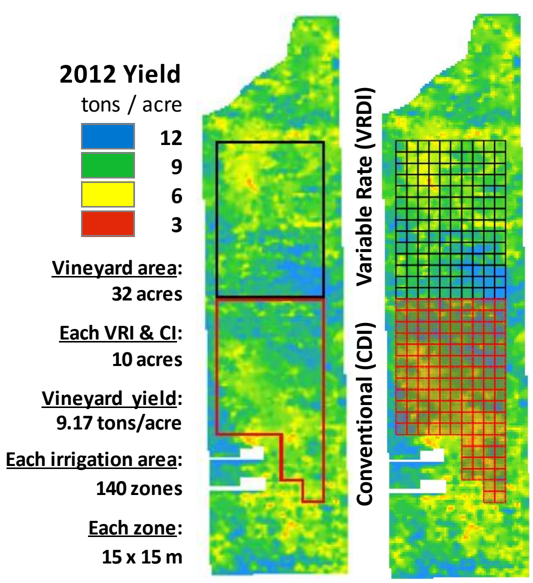

Figure 1. Variable Rate Irrigation system location in the field and adjacent Conventional Irrigation (control) grid. Both irrigation areas contain the full range of yield values present in the whole vineyard.

Table 1. Means, mean correlation distance (MCD) and Cambardella index (Cmbl) for variable rate (VRDI) and conventional irrigation (CDI) in 2012 (before VRDI deployment), 2013 and 2014

		Mean				MCD				Cmbl			
		2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015
Yield *	VRDI	8.9	7.7	10.1	5.1	50.3	11.1	61.2	18.3	6.2	17.7	5.3	15.2
	CDI	8.9	7.4	8.7	4.6	43.4	32.8	45.5	39.2	6.4	4.5	3.6	4.0
NDVI **	VRDI	0.79	0.86	0.91	0.89	53.7	29.9	62.3	46.1	8.8	10.2	7.8	11.3
	CDI	0.78	0.83	0.85	0.84	33.2	33.0	34.7	33.9	16.4	8.5	7.6	8.1

* Yield means in tons/acre ** NDVI Means as % of maximum
MCD = mean correlation distance Cmbl = Cambardella index

Table 2. Average yield and water use efficiency of variable rate and conventional irrigation in all four years of the study

Year	Yield (tons/acre)		Gain VRDI/CDI (%)	WUE (tons/acre-foot)		Gain VRDI/CDI (%)
	VRI	CI		VRI	CI	
2012	8.9	8.9	**0.0**	5.93	5.93	**0.0**
2013	7.7	7.4	**4.1**	5.63	4.93	**14.2**
2014	10.1	8.7	**16.1**	7.43	7.08	**4.9**
2015	5.1	4.6	**10.9**	4.27	3.65	**17.1**
Average			**10.3**			**12.1**

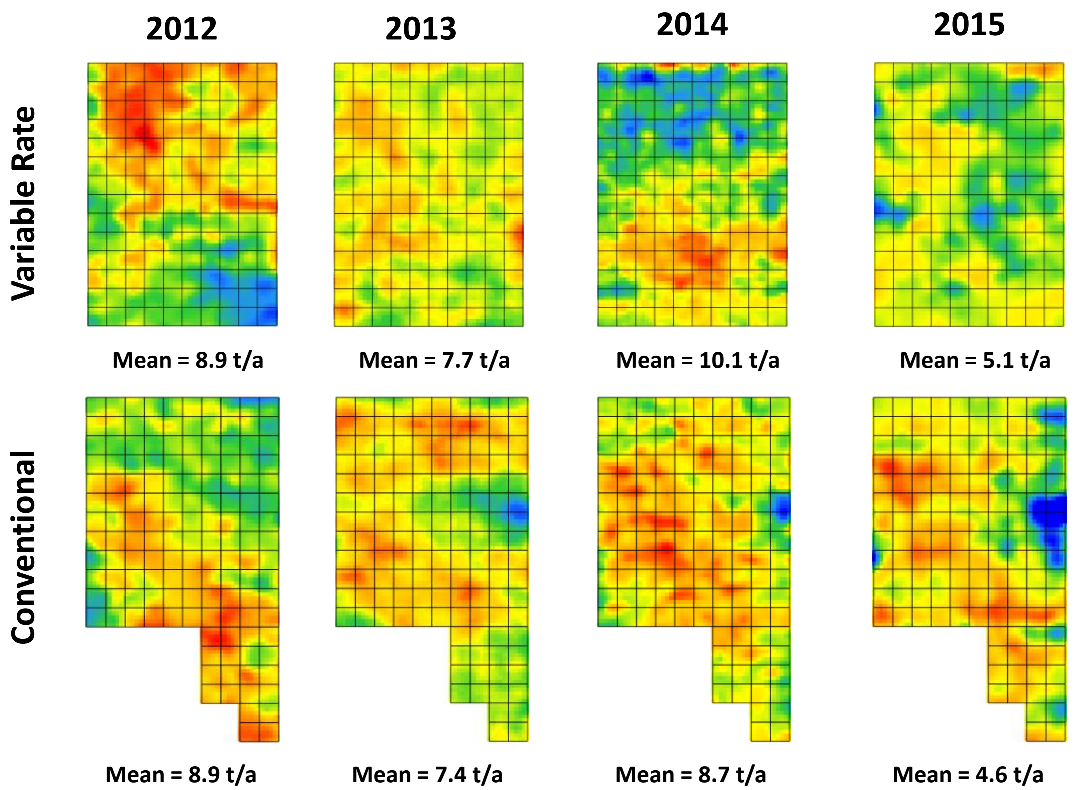

Figure 2. Normalized yield maps (zero mean and unit variance) for VRDI and CDI in 2012 (before the VRDI system was installed), 2013, 2014 and 2015.

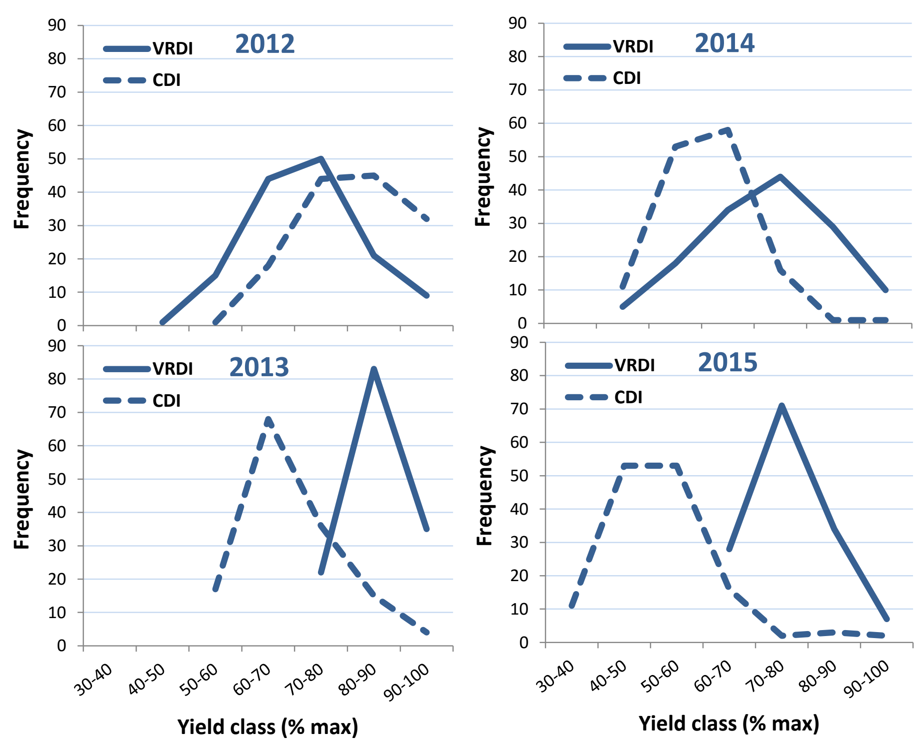

Figure 3. Yield shifts due to VRDI during 3 years compared to the year prior to implementation (2012)

Creating Actionable Intelligence

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At Bowles Farming Company the utilization of technology to manage variability is nothing new. Satellite imagery and variable-rate application technologies have been utilized since 2000. More recently Bowles hired Danny Royer as the Vice President of Technology to even further its efforts to leverage technology to make better decisions on the farm. The role of the Vice President of technology is to prepare the farm for the future by researching, developing and integrating technology solutions into the farming operation.

At Bowles, a multi-pronged approach to creating action out of our intelligence has been taken. The first prong is Data Collection or the gathering of information. The second prong is Data Analytics, how do we look at this data and what problems are we trying to solve with it. Lastly is Automation, developing systems and processes to take actions. Each prong is evaluated with its primary intention in mind. Meaning, many tools existing in the space today have pieces that they dominate their space in, but do not provide a viable full circle solution. Therefore, a tool that excels in GIS Data Collection capabilities, but not in reporting is measured with the intent of being a Data Collection tool, not a Data Analytics tool. Full circle solutions will be challenging to develop until the market has vetted out the increasing number of sensor and analytics solutions. Therefore, we have decided to focus our attention on finding more direct and single competency-centric solutions.

In 2017 Bowles will be focusing its R&D attention on remote sensors like drones and other on the ground environmental sensors. We will be exploring analytics and reporting tools to meet our in the field and office operational needs. A large area of focus will also be in developing management zones within given fields. The management zones will be created based on the spatial variability of many factors such as soil, imagery and yield. Lastly, in 2017, we will be installing our first irrigation automation systems and will also begin exploring robotic solutions for infield operational activities.

All of our research is ultimately focused on optimizing the productivity of our land for the long term. The natural resources required to grow food and fiber are precious and becoming increasingly more valuable. Our R&D efforts are driven by Bowles Farming Company's desire to be a leader in water conservation and environmental stewardship. We are leveraging the improved intelligence from technology on our farm to not only optimize the productivity of our land but also play our part in feeding a growing world using less water, less energy and less labor.

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2017

Session #8

Water Sustainability

Session Chairs:

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Dan Munk

SGMA Implementation and Regional Water Management Sustainability

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The Sustainable Groundwater Management Act was signed into law on September 16, 2014. Known as SGMA, this legislation is perhaps the most significant California water management legislation in decades and will serve as the catalyst for comprehensive sustainable water management locally, regionally, and statewide. The SGMA encourages local and regional management of groundwater through an understanding of water budgets. Balanced water budgets will require a comprehensive plan for both groundwater and surface water use.

Although the State has the responsibility to oversee the implementation of SGMA, it will be through local and regional efforts to develop and implement the plans and practices pursuant to sustainability. The California Department of Water Resources (DWR) is the state agency with primary responsibility for implementing the framework for sustainable groundwater management including the evaluation of the adequacy of initial groundwater sustainability plans (GSPs) and local agencies progress toward achieving sustainability through the evaluation of the implementation of those GSPs. Existing local agencies with water management responsibility may form as new groundwater sustainability agencies (GSAs) and manage groundwater resources on a basin or sub-basin scale. The State Water Resources Control Board is the state agency with primary responsibility for enforcing SGMA if the local agencies are unable to do so. In order to avoid State intervention, GSAs must form by June 30, 2017 and will be responsible for managing groundwater sustainably within 20 years through the development and implementation of GSPs. DWR intends to encourage the use of Integrated Regional Water Management (IRWM) efforts to advance the develop and implementation of GSPs which must be developed as early as 2020 and identify the necessary policies, funding, data collection, and actions necessary to achieve sustainable management of 127 high and medium priority groundwater basins.

DWR will seek to assist local and regional GSAs to manage groundwater sustainably for long-term reliability, for economic, social, and environmental benefits, for current and future beneficial uses, and as an integral part of broader sustainable water management throughout California.
To achieve this goal, DWR has developed a Strategic Plan with the following objectives to guide SGMA implementation over the next two decades. http://www.water.ca.gov/groundwater/sgm/pdfs/DWR_GSP_DraftStrategicPlanMarch2015.pdf.

Objective 1: Develop a Framework for Sustainable Groundwater Management
Providing a structure that will enable GSA's to achieve success will require many factors be addressed. This objective will address basin boundaries and prioritization, GSP formulation and content, BMP's, and water budgeting. In order to address directives from the Sustainable

Groundwater Management Act, DWR will develop regulations to inform and support regional efforts.

Objective 2: Provide Statewide Technical Assistance to Groundwater Sustainability Agencies

Providing technical assistance to GSA's will be crucial in enabling their success in managing their groundwater basins. GSA's will depend on easily accessible data and will be able to access this information via an online information system. Well standards and water conservation assistance will also be addressed.

Objective 3: Provide Statewide Planning Assistance to Support Groundwater Sustainability

DWR's *Bulletin-118* provides a systematic evaluation of groundwater basins in California, and will be updated to reflect critical information, including basin boundaries, groundwater quality data, yield data, and water budgets. This information will support and inform statewide water planning and assessment, including water budgeting, via DWR's *California Water Plan* (*Bulletin-160*). DWR will also provide information to support local groundwater recharge projects.

Objective 4: Assist State and GSA Alignment and Provide Financial Assistance

Strong alignment and collaboration between and amongst local, regional, and State agencies will be critical to achieving sustainable groundwater management statewide. DWR will provide venues for communication and engagement, educational materials, and facilitation services, as well as financial assistance to help ensure success.

Objective 5: Provide Interregional Assistance

Achieving this objective will require DWR to support regional water managers with information on water reliability, storage and conveyance opportunities, water available for replenishment, and updated surface- groundwater interactions.
DWR has already begun taking actions to meet these objectives and will continue to do so over the coming years to promote and support sustainable water management.

Since the passage of SGMA two years ago DWR has taken the following actions:

- Initiated a robust and intensive communication and outreach process with key audiences including state, federal, regional, local agencies, tribal governments, environmental, environmental justice, and agricultural interests, and universities. http://www.water.ca.gov/groundwater/sgm/outreach.cfm

- Availed facilitation services to prospective GSA formation efforts.

- Developed and adopted two emergency regulations using an expedited process through the California Water Commission. The first regulation, adopted on October 21, 2015, governs changes requested by local agencies to groundwater basin boundaries. The second regulation, adopted on May 18, 2016, governs required contents, process, and state review and approval of groundwater sustainability plans. http://www.water.ca.gov/groundwater/sgm/basin_boundaries.cfm http://www.water.ca.gov/groundwater/sgm/gsp.cfm

- Updated groundwater basin boundaries (CA DWR's Bulletin 118). http://www.water.ca.gov/groundwater/bulletin118/update.cfm
- Updated California's identification of groundwater basins experiencing critical conditions of overdraft. The first update since 1980. http://www.water.ca.gov/groundwater/sgm/cod.cfm
- Implemented interactive web based tools supporting noticing by newly created groundwater sustainability agencies, submittal of water budget information by adjudicated basins, and development of a water management planning tool that allows the public to overlay different political and jurisdictional layers affecting water management. https://gis.water.ca.gov/app/boundaries/
- Published final Best Management Practices (BMPs), as series of five documents that provide regulatory clarification, technical guidance, and general examples to assist groundwater sustainability agencies (GSAs) and inform local agencies and stakeholders. BMPs are intended to provide clarification, guidance, and examples to help Groundwater Sustainability Agencies develop the essential elements of a Groundwater Sustainability Plan (GSP). http://www.water.ca.gov/groundwater/sgm/bmps.cfm
- Prepared a report on water available for replenishment (WAFR) in California. This report presents DWR's best estimate, based on available information, of water available for replenishment of groundwater in the state. Public comments received by March 10, 2017 will be considered for publication of a final report later this year. http://www.water.ca.gov/groundwater/sgm/wafr.cfm

A "Sustainable Groundwater Management Act" Implementation Update

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Introduction

The California "Sustainable Groundwater Management Act of 2014 (SGMA)" is now in the implementation phase. The most intense implementation efforts have occurred in groundwater areas declared "critically over-drafted" by the California Department of Water Resources under authority granted to them under SGMA (Figure 1). The largest contiguous area of critical over-draft is the San Joaquin Valley and as a result the vast majority of the implementation activities have occurred in the Valley. The Fresno State campus extracts groundwater for both agricultural and drinking water supplies and therefore has a vested interest in area groundwater management. The campus is located in the Kings Sub-basin (Figure 2) of the Valley groundwater system and has been directly involved in the formation of a "groundwater sustainability agency" needed to implement the requirements of SGMA. The following briefly describes the core elements of SGMA then describes local implementation efforts to date which are being duplicated to a similar degree throughout the critically over-drafted basins in the State. The local description includes the nuts-and-bolts of the formation of a new special district within the Kings Sub-basin within the Valley, the "North Kings Groundwater Sustainability Agency Joint Powers Authority" (North Kings GSA) which is adopting the processes needed to manage a locally-circumscribed area of groundwater in conformance with SGMA. In addition, this paper will outline the larger water management context and coordination needs of SGMA. Many other recent California water management requirements will need to be considered and integrated with SGMA's implementation strategies.

Basic SGMA

SGMA has four substantive elements. The first is the definitions including the descriptions of where SGMA is applicable. The applicability definitions focus special attention on groundwater use locations that have had high extraction patterns long enough to be easily identified as priorities (critically over-drafted) for implementation of the law. The second is the recognition of the comparatively local nature of groundwater *use* and a resulting preference for local institutions to take the leadership role in implementation of the law. The third is the conditions that must be prevented or remedied (summarized as "undesirable results" of extraction) and the fourth "a plan or plans" with implementation strategies to achieve "sustainability". Not much beyond these activities is elucidated in the law with two exceptions. First, the Department of Water Resources is authorized to: (1) determine groundwater basin boundaries; (2) declare which basins or sub-basins are critically over-drafted, and; (3) approve the formation of the local management entities if they meet the conditions set forth in regulations. Second, the California Water Resources Control Board is designated as the default SGMA groundwater management agency if no local entities rise to meet the legal and technical requirements. The sum of these processes still leaves broad areas of management activities in the hands of the local agencies and organizations who assume any groundwater management responsibilities. For example, groundwater management is data intensive and the sources of data will range from individuals who have heretofore not been involved in such data efforts to sophisticated networks operated by overlying agencies. The local efforts will hinge on the success of data-gathering in order to be able to understand the actual

Figure 1 – Critically Over-drafted Basins

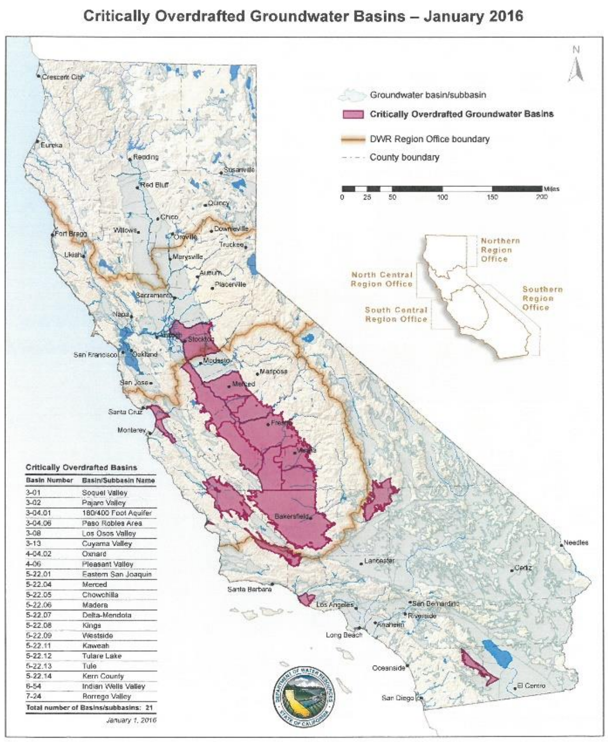
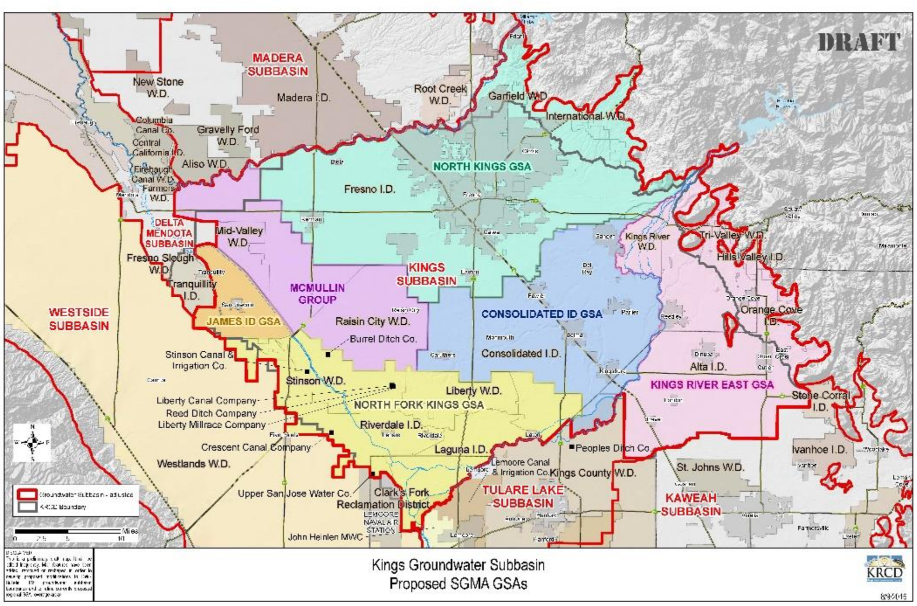


Figure 2 – SGMA GSA Formation in Kings Sub-basin



conditions and apply the remedies needed for management. Additional thorny management challenges are apparent such as how to manage extraction rates to arrest "undesirable results" of over-draft and achieve "sustainability". That eventuality has not yet been discussed at any level of the relevant organizing entities and undoubtedly is creating anxiety with individual extractors. The bottom line is that many organizational aspects of SGMA will have to be very carefully designed (in the "sustainability plans") and then implemented which perhaps will take more time than the law assumed or allows.

The North Kings GSA SGMA Implementation Process

It is safe to say that the principal implementation efforts of SGMA to date have been the building of the local agencies that are ostensibly applying to the State for the authority to manage local groundwater. In fact, that is the initial technical deadline in SGMA, local public water agencies have until June 2017, to form a qualified entity. The North Kings GSA is representative of such efforts and the process it has used to organize is as follows.

In August 2015, the North Kings GSA was initiated by Fresno Irrigation District, an eligible "public water agency" under SGMA. Fresno Irrigation District (FID) and the Cities of Fresno and Clovis, both wholly within the boundary of FID, have been involved in groundwater management activities together for a long time. Those three entities have made arrangements and developed projects to maximize the utility of both their groundwater and surface water supplies collectively for close to fifty years (as represented by "Leaky Acres"). They, along with Fresno County, provide the bulk of the representation of groundwater use and users in the self-selected boundary. FID began the process by inviting any and all groundwater using entities and representative individuals within the circumscribed boundary. FID also invited potential partners who could assist with groundwater management activities but are not necessarily "extractors', such as the Fresno Metropolitan Flood Control District which shares its storm water management facilities for groundwater recharge. Upon engaging all the interested parties, the potential representative entities included; FID, the City of Clovis, the City of Fresno, the County of Fresno, Garfield and International Irrigation Districts, the City of Kerman, Fresno State, Bakman Water Company, Biola Community Services District, Malaga County Water District and Pinedale County Water District. The first organizing document was a "memorandum of understanding (MOU)" that outlined the efforts needed to explore, study and evaluate the management responsibilities, authorities and governance alternatives. Currently, all but Malaga and Pinedale have remained to participate in a more permanent governance structure that came out of the MOU negotiations. Ostensibly the entities that dropped out will elect to develop their own structure and coordinate with the North Kings GSA or be represented by the County.

From August 2015 to October 2016 the fledgling organization held numerous meetings and went through a rigorous process of working with a full committee of the representative entities and individual or collective stakeholders to determine the scope and needs of the new organization and outline the functions and partners needed to accomplish the work. The effort included significant outreach and engagement with various parties as required under SGMA, including disadvantaged communities and individual groundwater user representatives. The work was guided by professional external facilitation offered through a grant from the CA Department of Water Resources. Ultimately the work resulted in a recommendation to form a "Joint Powers Authority" made up of eligible public agencies with their elected representatives serving on the

Board of Directors and formal "participation agreements" for entities that are not public agencies such as privately-held water companies who can then can participate on the Board as well. The North Kings GSA JPA met officially for the first time in November 2016. Since then the Board of Directors has met to adopt various other instruments and policies to begin the work including; obtaining fiscal management services, seeking qualifications proposals for technical and legal professional services and adopting State requirements for conflict of interest. The next large step for the agency will be to commission the construction of the local "groundwater sustainability plan (GSP)".

North Kings GSA and the Kings Sub-basin

The North Kings GSA area is within a portion of the State-identified Kings Sub-basin of the larger San Joaquin Valley groundwater system. The Sub-basin roughly encompasses an area from the base of the Sierra foothills on the east, the San Joaquin River on the north, the Kings River on the south and the Fresno Slough/James By-pass (a controlled distributary of the Kings River) on the west (Figure 2). Within the Sub-basin five other GSA areas have been identified besides the North Kings. Two have been organized through special legislation originated in the California Senate, approved in the Assembly and signed by the Governor. The Kings River East GSA, which has Alta Irrigation District as its core, was created by Senate Bill 37 and the North Fork Kings GSA along the southwestern border of the Sub-basin was created by Senate Bill 564. Two others are forming in processes similar to North Kings. Consolidated Irrigation District is tentatively forming a GSA in its service area in south central Fresno County and James Irrigation District along Fresno Slough has formed its own GSA. The remaining area, labeled on Figure 2 as the McMullin Group, is being organized by several public agencies but principally Fresno County. It is informative that five of the six GSAs have organized around the surface water supplies afforded their areas, while the sixth, McMullin, has no surface water to speak of other than temporary arrangements such as flood waters. Also of interest is that the James GSA has some surface water but a significant source of its supplies is groundwater obtained from well fields in the McMullin area.

A significant requirement of SGMA is for all GSAs in a sub-basin to develop coordination and integration of their groundwater sustainability plans. Fortunately for the Kings Basin there has been some aggregation of work already performed by the Kings River Conservation District (KRCD) which covers all of the Kings Sub-basin. The KRCD coordination provided thus far includes collecting groundwater data, developing a groundwater model and covering the same area with an "integrated regional water management plan" (Water Code Section 10530 et seq.) which has afforded the area access to significant grant funds for projects and work related to the Kings Sub-basin groundwater system. What is not clear is how the coordination and aggregation of the GSAs into complete Sub-basin work will continue in the future. While KRCD may be a logical choice, the ongoing arrangements will need sufficient structure to satisfy SGMA requirements and it is unclear what that structure will look like. Fresno County has also been providing a vehicle for discussion among the various parties involved in GSA formation. The County is a logical organizer for a significant portion of the ongoing processes as well, inasmuch as the County is the front door for groundwater extraction as they operate the water well construction permit process (as do many counties in the State). It appears some combination of the County and KRCD involvement is a likely ongoing relationship that could congeal the GSAs into the implementation strategies needed for proper sustainability plan implementation.

The Sustainability Framework

SGMA implementation is only part of a larger process of water sustainability activities under re-construction in California. Nonetheless it is perhaps the most important recent addition because it was the last unregulated portion of the water management system. Surface water rights, water quality and other beneficial uses of water have been regulated for some time. Recently many of the other regulated uses have been further modified with more intense management policies and those activities combined with SGMA beg for careful integration and coordination. The result of a broader, thoughtful integrated approach could be a more robust water sustainability framework. Some of the recent changes (since 2009) in water management requirements and actions with activities most directly linked to groundwater, and hence SGMA (in *italics*), include the following:

Table 1 – Recent Policy Changes Impacting CA Water Management

Action/Date	Impact	Link to groundwater
ESA BiOps updates for smelt and salmon - 2009	Reduced Delta exports	During drought forced SJR rights holders to use original source, reducing contract water to groundwater areas in SJV Friant service area
Delta Stewardship Council - 2009	New institutional arrangement that includes both water and environmental management duties with a watermaster to implement water use regulation	Long-term improvement of environment could allow more reliable in-Delta and Delta export water uses
SBx 7-7 Water measurement - 2009	More intense ag and urban water use measurement	Conserved groundwater stays in the ground
CASGEM - 2009	*Groundwater elevation measurement requirements*	*Better data on conditions feeds into SGMA*
CA Recycled Water Policy w/Salt and Nutrient Plans for groundwater, CV-SALTs in Central Valley - 2009	*Likely more stringent groundwater quality discharge standards in vulnerable areas, less stringent where appropriate*	*CV-SALTS will identify vulnerability zones for nitrogen and salts in groundwater basins*
Central Valley Flood Protection Plan - 2009	Requires levee improvements, some setback areas, potential flood easements	Flood easements could provide temporary water storage for later release for groundwater recharge
Central Valley Irrigated Lands Regulatory Update - 2012	*Added groundwater quality evaluations and controls to farm discharge requirements*	*Nitrogen management requirements in vulnerable soil/geology areas are a high priority*
The Right to Clean Drinking Water -2012	*Disadvantaged communities will get priority attention for improvements*	*Most problem systems/areas use groundwater sources, may accelerate implementation of actions to*

		improve groundwater in vulnerable areas
The Water Action Plan - 2014	Establishes priorities for State water management actions across all agencies and activities	Implementation includes groundwater management and SGMA
SGMA - 2014	*Brings groundwater use into water management system*	*Includes undesirable results of both quantity and quality clearly demanding integration with other described actions*
Drought Emergency Declaration - 2015	Established more stringent goals for urban and ag water use where appropriate	Conserves groundwater
Prop. 1 Water Bond Surface Storage Public Benefit Regulations - 2016	Defines public benefits eligible for state funding of new or expanded surface storage facilities	Expands but complicates traditional cost/benefit calculations for eligible projects, including benefits of groundwater recharge for quantity and quality improvements

Conclusions

SGMA implementation is under way in the areas designated as critically over-drafted in the San Joaquin Valley, but the process is moving somewhat unevenly. The organizations forming thus far are adding additional special districts to geographic areas already laden with many local government agencies and sub-dividing groundwater areas further than the logical areas the State initially designated; groundwater knows no institutional boundaries. The critical issue facing the new process includes weaving the smaller components into larger coordinated efforts in concert with both SGMA and the myriad of other water management requirements facing water management institutions and their leadership.

Literature Cited

Central Valley Water Awareness Committee – Leaky Acres and other recharge activities
http://www.centralvalleywater.org/water_awareness/education/groundwater_recharge.php

Central Valley Salt and Nitrate Build-up Addressed through Innovative Regulations

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CALIFORNIA'S CENTRAL VALLEY

The Central Valley (Valley) stretches 500 miles from the Oregon border to the Kern County/Los Angeles County line and is about 125 miles wide, bounded by the Sierras to the east and the Coast Range to the west. Its watersheds encompass 60,000 square miles or almost 40% of the land in the State of California. The region includes four hydrologic regions: Sacramento River Valley to the north, the drier San Joaquin River Valley to the south, the semi-arid Tulare Basin at the southernmost end, and the Delta where the San Joaquin and Sacramento Rivers connect and flow to San Francisco Bay. The Valley is home to nearly 8 million people or 20% of the state's population. It is one of the world's most productive agricultural regions, with hundreds of different crops grown. Most of the Valley's agricultural productivity relies on irrigation from both surface water diversions and groundwater pumping. The Valley also supports thousands of food production facilities for fruit, vegetable, and nut processing, specialty foods, dairy products, animal packing, grain milling, wineries, and many more.

NITRATE AND SALT BUILD-UPS, UNSAFE DRINKING WATER IN PORTIONS OF THE CENTRAL VALLEY

Over the last 150 years, increased agricultural, municipal, and industrial activities, coupled with population growth, have resulted in dramatic increases in salts and nitrates in surface water, groundwater, and soils—a situation that continues to worsen. Communities rely on these water sources to support beneficial water uses, including agriculture, industry, drinking water supplies, and the environment. The elevated salt and nitrate concentrations impair, or threaten to impair, the region's water and soil quality, which in turn threaten drinking water supplies, agricultural and industrial productivity, and quality of life. The accumulations are causing poor water quality and, in some communities, unsafe drinking water. To restore water quality and preserve the future of the Valley, new and improved agricultural, industrial, and municipal water system management practices are needed to reduce salt and nitrate discharges, and first and foremost, to protect and provide safe drinking water.

STATE WATER BOARD AND CENTRAL VALLEY WATER BOARD REGULATE WATER QUALITY

Agricultural, municipal and industrial waste discharges of nitrates and salts are regulated by the Central Valley Regional Water Quality Control Board (Central Valley Water Board), under the State Water Resources Control Board (State Water Board). Two Basin Plans provide the basis for regulating water quality—Sacramento River-San Joaquin Basin Plan and the Tulare Lake Basin Plan. Additionally, in the Delta, which is in several agency jurisdictions, the State, Central Valley, and San Francisco Bay Water Boards work together on water quality. In general, the current water quality regulations, established more than 40 years ago, do not include the management tools and requirements to address effectively the emerging problem of nitrate in drinking water and the long-term problem of salt accumulation in the Central Valley.

MUNICIPAL, DOMESTIC, AND AGRICULTURAL WATER SUPPLIES ARE MOST SENSTIVE

Recent technical studies show that the beneficial uses most sensitive to salt and nitrate are Municipal and Domestic Supply (MUN) [Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply] and Agricultural Supply (AGR) [Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation (including leaching of salts), stock watering, or support of vegetation for range grazing].

CHALLENGES AHEAD

The Central Valley faces significant challenges for the long-term management of salt and nitrate:

- More salts enter the Lower San Joaquin and Tulare Lake Basins than leave or are removed.
- Dams and imported water supplies, so important for the Valley economy, have reduced the natural flushing of salt and increased the amount brought into the Valley.
- Groundwater use has increased to meet water demands.
- Broad expanses of groundwater aquifers have been affected by legacy nitrate concentrations.
- Salt concentrations in the groundwater are naturally high in some areas and increasing in most areas.
- There are few economically feasible options for removing salt from the Valley.

CV-SALTS INIATIVE IS FIRST STEP TOWARD NEW SOLUTIONS FOR MANAGING SALTS AND NITRATES

Solutions for addressing the threat to water supplies and soils from salts and nitrates are complex, multi-faceted, and will take time and funding to implement. In 2006, a broad coalition of representatives from agriculture, cities, industry, environmental and environmental justice interests, and state and federal regulatory agencies started to develop an environmentally and economically sustainable plan for managing salts and nitrates. This effort is known as the Central Valley Salinity Alternatives for Long-Term Sustainability initiative, or CV-SALTS. In 2008, the Central Valley Salinity Coalition (CVSC) formed to represent the stakeholder groups working with the State Water Board and Central Valley Water Board in this effort. Together, the State agencies and CVSC have developed a *Salt and Nutrient Management Plan* to address the salt and nitrate challenges.

SALT AND NITRATE MANAGEMENT PLAN OFFERS NEW REGULATORY FRAMEWORK

The last decade of technical study and stakeholder collaboration culminated in the development of the CV-SALTS *Salt and Nitrate Management Plan* (SNMP). The SNMP includes results of extensive technical studies, recommended actions and changes to current regulations, and milestones and timelines, that together address legacy and ongoing salt and nitrate accumulation issues. It establishes the minimum or default expectations for managing salts and nitrates in discharges to surface and groundwater. Given the sheer size and variability of environmental conditions and sources of salt and nitrate in the Valley, the SNMP takes a practical, adaptable approach for applying management requirements tailored to local conditions and needs. Implementation would be phased, allowing resources to be allocated to the most significant water quality priorities first.

SNMP LONG-TERM OUTCOMES

The SNMP was developed to achieve five long-term outcomes: (1) sustain the Central Valley's lifestyle; (2) support regional economic growth; (3) retain a world-class agricultural economy; (4) maintain a reliable, high-quality water supply for municipal, agricultural, and industrial uses; and (5) protect and enhance water quality in Central Valley streams, rivers, and groundwater basins.

SAFE DRINKING WATER, BALANCED NITRATES AND SALTS, RESTORED GROUNDWATER

The SNMP provides the over-arching framework for managing salt and nitrate in the Central Valley by establishing three prioritized management goals to guide implementation: (1) ensure safe drinking water; (2) work to achieve balanced salt and nitrate loadings; and (3) implement a long-term groundwater restoration program. Notably, required and voluntary activities leading to salt and nitrate balance are already underway, including preparation and implementation of nutrient management plans, improved irrigation practices, real-time management of discharges, pilot studies, monitoring, and research. Restoring the region's groundwater basins will be a long-term, resource-intensive effort. The SNMP proposes a framework to support, continue, and expand current efforts and to establish funding and management structures to address the long-term challenges.

SNMP OFFERS A MORE FLEXIBLE REGULATORY FRAMEWORK

Existing State regulations limit the Central Valley Water Board ability to consider new, innovative salt or nitrate management strategies, particularly as they relate to providing safe drinking water. The SNMP recommends changes to the existing Basin Plans that govern water quality in the Valley. The recommended changes offer a more flexible regulatory framework. Specifically, salt and nitrate management decisions would be made at the local or regional level, with State oversight. Local decision-making would develop effective solutions by considering local conditions and available management strategies. The proposed policies would also allow dischargers to develop independent data for their discharge area. Using this data, a discharger or group of dischargers could propose revised permit requirements if default requirements were not applicable to local conditions and discharges. The proposed recommendations will be considered as amendments to the Basin Plans by the Central Valley Water Board and State Water Board.

KEY ELEMENTS OF THE SNMP

Assessment of Current Conditions: The SNMP identifies current ambient water quality and estimated available assimilative capacity in upper, lower, and production zones of groundwater basins and sub-basins.

Regulatory Analyses: The SNMP describes research to define reasonable protection of existing and probable future beneficial uses of water for Municipal and Domestic Supply (MUN) and Agricultural Supply (AGR).

Technical Analyses: The SNMP describes studies to provide the basis for recommendations for the short and long-term management of salt and nitrate throughout the Central Valley, including nitrate drinking water treatment and local and regional salinity management needs, such as a regulated brine line for salt export.

Archetype/Prototype Studies ("Proofs of Concept"): To better explain potential policy changes (and how they might work in practice), the SNMP includes Proofs of Concept studies that provide examples and/or guidelines for consideration when implementing various elements of the SNMP.

Recommended Policies: The SNMP identifies 11 proposed policy changes or clarifications to the Basin Plans to facilitate SNMP implementation by providing new authorities for the Central Valley Water Board to supplement its existing authorities. These proposed changes are described in additional supporting fact sheets available on the CV-SALTS website.[1]

The SNMP is also implemented through three Central Valley Water Board Basin Plan amendments planned for adoption in 2017:

> *Municipal Supply in Agricultural Areas*: Incorporating a process into the Basin Plans for determining appropriate designation and level of protection of MUN in agriculturally dominated water bodies;
> *Salt and Boron in the Lower San Joaquin River*: Setting salt/boron water quality objectives and adding/modifying an implementation program for the Lower San Joaquin River; and
> *Beneficial Uses in the Tulare Lake Basin*: Evaluating the designation/de-designation of the MUN and AGR beneficial uses in a portion of the Tulare Lake Bed Groundwater Basin

EXAMPLE OF REGULATORY OPTIONS FOR NITRATE MANAGEMENT

If the Central Valley Water Board and the State Water Board adopt the proposed policies related to nitrate management, nitrate dischargers such as farms, dairies, wastewater treatment plants, and

[1] http://www.cvsalinity.org/index.php/docs/central-valley-snmp/163-central-valley-salt-nitrate-management-plan.html

certain industries would have the following three compliance options. Currently, “traditional permitting” is the only option available.

Traditional Permitting. The traditional, or current, permitting approach uses existing regulatory Waste Discharge Requirements (WDRs) and Conditional Waivers issued by the Central Valley Water Board. Each individual discharger must meet specified water quality standards at the discharge point to receiving waters, the base of the root zone, or the top of the groundwater aquifer, depending on the discharger. This approach may be more straightforward for a single discharger, however, in some areas it may not be possible to meet discharge requirements or address nearby nitrate contamination of drinking water.

Management Zones. *This is a new regulatory option*. In local or regional areas with high priority nitrate problems, nitrate dischargers would work collectively with water providers, local government, and others to establish a plan to provide safe drinking water for users with nitrate-contaminated water and identify the reasonable and feasible best management practices and treatment strategies that will establish a nitrate balance, within the defined management area. The management zone plan would also develop a long-term plan for restoring groundwater to meet applicable water quality objectives. The SNMP recommends the inclusion of a Groundwater Management Zone Policy within the Basin Plans to define a proper management zone and the criteria for approval by the Central Valley Water Board. The Central Valley Water Board would review, approve, and oversee the management zones and the local management plans. The new management zone option provides an opportunity for dischargers and others to identify cooperative actions that may be more cost-effective and efficient than individual actions.

Alternative Nitrate Permitting. *This is a new regulatory option*. In some areas of the Central Valley, and for some types of dischargers, both the traditional permitting and management zone designation may not be feasible, reasonable, or practicable. Accordingly, the SNMP Nitrate Permitting Strategy proposes an alternative permitting approach. This approach would allow an individual discharger to propose an alternate plan and timeline to achieve water quality goals and objectives in the Basin Plan. For example, depending on local conditions, such a plan could address high priority drinking water needs immediately while implementing a longer-term plan to meet nitrate discharge requirements.

NEXT STEPS

January 2017: SNMP released for Public Review

March 9, 2017: SNMP presented to the Central Valley Water Board for discussion at an informational workshop.

October 2017: Draft Basin Plan Policy Amendments that reflect the recommended SNMP policy changes (for the Tulare Lake Basin and for the Sacramento River and San Joaquin River Basin Plan)

February 2018: Basin Plan Amendments Considered by the Central Valley Water Board

April 2018: Basin Plan Amendments Approved by the Central Valley Water Board

June 2018: SNMP approved by the State Water Resource Control Board

August 2018: SNMP implementation, following approval by the California Office of Administrative Law (OAL) and approval of surface water portions by the U.S. Environmental Protection Agency (EPA)

CONNECT, STAY INFORMED, GET INVOLVED

Central Valley Water Board:
www.waterboards.ca.gov/centralvalley/water_issues/salinity/index.shtml

CV-SALTS: www.cvsalinity.org.

American Society of Agronomy
California Chapter

2017

Session #9

Biostimulants

Session Chairs:

Eric Ellison & Dave Holden

Overview of Biostimulants for Agriculture

Patrick Brown, Professor, University of California, Davis

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frontiers in Plant Science

MINI REVIEW
published: 27 August 2015
doi: 10.3389/fpls.2015.00671

Biostimulants in agriculture

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Keywords: biostimulants, mode of action, plant signaling, stress response, endophytic microorganisms, microbial extracts

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Crop Science and Horticulture, a section of the journal Frontiers in Plant Science

Received: *12 June 2015*
Accepted: *13 August 2015*
Published: *27 August 2015*

Citation:
Brown P and Saa S (2015) Biostimulants in agriculture. Front. Plant Sci. 6:671. doi: 10.3389/fpls.2015.00671

The past decades have witnessed tremendous growth in the use of biostimulants in agriculture and it is estimated that biostimulants will grow to $2 billion in sales by 2018 (Calvo et al., 2014). Recognizing the need to establish a legal framework for the marketing and regulation of these products the European biostimulants industry council (EBIC, 2012) defined plant biostimulants as "containing substance(s) and/or micro-organisms whose function when applied to plants or the rhizosphere is to stimulate natural processes to enhance/benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, and crop quality."

There is a clear need to improve our understanding of biostimulant function so that the efficacy of these materials can be improved and the industrial processes can be optimized. Determining the function of this class of products, however, has proven to be immensely difficult (Khan et al., 2009; Carvalhais et al., 2013; Rose et al., 2014). This is in large part due to the diversity of sources of these materials and the complexity of the resulting product, which in most cases will contain a significant number of poorly characterized molecules. Since biostimulants are derived from an incredibly diverse set of biological and inorganic materials (Calvo et al., 2014) including microbial fermentations of animal or plant feedstock, living microbial cultures, macro, and micro-alga, protein hydrolysate, humic, and fulvic substances, composts, manures, food, and industrial wastes prepared using widely divergent industrial manufacturing processes, it is illogical to assume that there is a single mode of action.

The definition of biostimulants adopted by EBIC specifies that these materials should not function by virtue of the presence of essential mineral elements, known plant hormones or disease suppressive molecules. Accepting this definition, we hypothesize that biostimulants benefit plant productivity by interacting with plant signaling processes thereby reducing negative plant response to stress. This hypothesis recognizes the wealth of recent research demonstrating that plant response to stress is regulated by signaling molecules that may be generated by the plant or its associated microbial populations (Marasco et al., 2012; Bakker et al., 2014; Vandenkoornhuyse et al., 2015). Biostimulants may either directly interact with plant signaling cascades or act through stimulation of endophytic and non-endophytic bacteria, yeast, and fungi to produce molecules of benefit to the plant (**Figure 1**). The benefit of the biostimulant is derived from the reduction in assimilates that are diverted to non-productive stress response metabolism.

In this research topic the effects of biostimulants on plant productivity is examined in 10 research papers. Colla et al. (2014), soil-applied a plant-derived protein hydrolosate and demonstrated improved growth and nitrogen assimilation in seedlings of pea, tomato, and corn. The use of giberrellic acid (GA) deficient mutants and classic auxin response treatments suggests this material benefits plant growth by mimicking the actions of indole acetic acid (IAA) and GA.

Ertani et al. (2014) observed the effects of alfalfa hydrolosate (AH) and red grape extract (RG) on nitrogen metabolism and growth of pepper plants (Capsicum chinensis). Significant, dose dependent changes were observed in a wide range of sugars, phenols, and quarternary nitrogen containing molecules. In almond grown under high nutrient supply conditions biostimulants derived from either seaweed or microbial fermentation of cereal grains, had a marked positive effect on shoot growth and leaf area (Saa et al., 2015). Under conditions of low nutrient supply

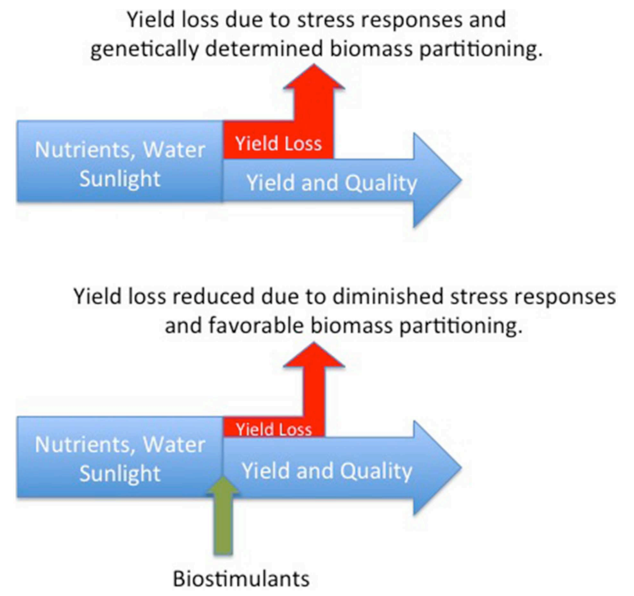

FIGURE 1 | Non-lethal stress is experienced to varying degrees by all crop plants resulting in a loss of productivity as assimilates are diverted to stress response metabolism (top figure). It is hypothesized that biostimulants interacting with plant signaling processes reduce the extent of negative plant response to stress and increase the allocation of biomass to the harvested yield component.

the benefit was less significant though there was a marked increase in rubidium uptake (an analog for K uptake). A differential response to the application of a nitrophenolate based biostimulant (Przybysz et al., 2014) was observed with significant and consistent growth and photosynthesis improvements under drought and heavy metal stress (platinum) and inconsistent growth benefit under non-stressed growth conditions.

Evidence that biostimulants may enhance macro nutrient uptake has been reported previously (Calvo et al., 2014; Rose et al., 2014) and have been ascribed to an effect on sink activity or stimulation of nitrogen metabolism. Foliar application of a biostimulant derived from microbial fermentation of cereal grains (Tian et al., 2015) greatly enhanced the movement of foliar applied zinc in sunflower. Using high resolution elemental mapping techniques (μ-Xray Florescence) the movement of Zn to the phloem following application of a combination of biostimulant and zinc sulfate was elegantly demonstrated. This research did not determine if the addition of the biostimulant enhanced Zn uptake by increasing Zn movement through the leaf surface and subsequent transport of Zn to the phloem, or if the enhanced transport was a result of increased sink strength as was observed when this same product was used in Almond (Saa et al., 2015).

Vergnes et al. (2014) used foliar application of an essential oil derived from *Gaultheria procumbens* and demonstrated significant induced resistance on *Arabidopsis* leaves inoculated with the fungal pathogen *C. higginsianum*. The authors concluded that the essential oil from *G. procumbens* could be a valuable natural source of methyl salicylic acid (MeSA) for biocontrol applications. The application of salicylic acid (SA) has been shown to have negative effects on plant productivity either as a result of direct toxicity or changes in allocation of assimilates to plant defense responses. This response was also observed by Ghazijahani et al. (2014) who noted that the negative effects of SA can be mitigated by co-application of citric acid.

Many biostimulants contain simple and complex carbohydrates that when applied to plant may alter metabolism by directly acting as a source of energy for endophytic and non-endophytic microbial populations or acting as signaling molecules. The complexity of the roles of carbohydrates in plant immunity was reviewed by Trouvelot et al. (2014), who suggested that carbohydrates activate defense reactions by pathogen associated molecular patterns (PAMPs), microbe associated molecular patterns (MAMPS), and damage associated molecular patterns (DAMPs). The authors highlight the main classes of carbohydrates that are involved in plant immunity (beta-glucans, chitin, pectin) and discuss how the degree of polymerization and types of oligosaccharides affects biological activity. This review further suggests that carbohydrates in biostimulants may act by beneficially manipulating plant signaling cascades.

The great diversity of plant response to biostimulants highlights the challenges faced by researchers. Many plant responses to biostimulants cannot be explained by our current understanding of plant processes and while this represents a challenge, it also presents a great opportunity.

References

Bakker, M. G., Schlatter, D. C., Otto-Hanson, L., and Kinkel, L. L. (2014). Diffuse symbioses: roles of plant-plant, plant-microbe and microbe-microbe interactions in structuring the soil microbiome. *Mol. Ecol.* 23, 1571–1583. doi: 10.1111/mec.12571

Calvo, P., Nelson, L., and Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. *Plant Soil* 383, 3–41. doi: 10.1007/s11104-014-2131-8

Carvalhais, L. C., Muzzi, F., Tan, C. H., Hsien-Choo, J., and Schenk, P. M. (2013). Plant growth in *Arabidopsis* is assisted by compost soil-derived microbial communities. *Front. Plant Sci.* 4:235. doi: 10.3389/fpls.2013.00235

Colla, G., Rouphael, Y., Canaguier, R., Svecova, E., and Cardarelli, M. (2014). Biostirnulant action of a plant-derived protein hydrolysate produced through enzymatic hydrolysis. *Front. Plant Sci.* 5:448. doi: 10.3389/fpls.2014.00448

Ertani, A., Pizzeghello, D., Francioso, O., Sambo, P., Sanchez-Cortes, S., and Nardi, S. (2014). Capsicum chinensis L. growth and nutraceutical properties are enhanced by biostimulants in a long-term period: chemical and metabolomic approaches. *Front. Plant Sci.* 5:375. doi: 10.3389/fpls.2014.00375

EBIC. (2012). What are biostimulants? Available online at: http://www.biostimulants.eu/about/what-are-biostimulants

Ghazijahani, N., Hadavi, E., and Jeong, B. R. (2014). Foliar sprays of citric acid and salicylic acid alter the pattern of root acquisition of some minerals in sweet basil (Ocimum basilicum L.). *Front. Plant Sci.* 5:573. doi: 10.3389/fpls.2014.00573

Khan, W., Rayirath, U. P., Subramanian, S., Jithesh, M. N., Rayorath, P., Hodges, D. M., et al. (2009). Seaweed extracts as biostimulants of plant growth and development. *J. Plant Growth Regul.* 28, 386–399. doi: 10.1007/s00344-009-9103-x

Marasco, R., Rolli, E., Ettoumi, B., Vigani, G., Mapelli, F., Borin, S., et al. (2012). A Drought resistance-promoting microbiome is selected by root system under desert farming. *PLoS ONE* 7:48479. doi: 10.1371/journal.pone.0048479

Przybysz, A., Gawronska, H., and Gajc-Wolska, J. (2014). Biological mode of action of a nitrophenolates-based biostimulant: case study. *Front. Plant Sci.* 5:713. doi: 10.3389/fpls.2014.00713

Rose, M. T., Patti, A. F., Little, K. R., Brown, A. L., Jackson, W. R., and Cavagnaro, T. R. (2014). "A meta-analysis and review of plant-growth response to humic substances: practical implications for agriculture," in *Advances in Agronomy*, Vol. 124, ed D. L. Sparks (New York, NY: Academic Press), 37–89.

Saa, S., Olivos-Del Rio, A., Castro, S., and Brown, P. H. (2015). Foliar application of microbial and plant based biostimulants increases growth and potassium uptake in almond (Prunus dulcis Mill. D. A. Webb). *Front. Plant Sci.* 6:87. doi: 10.3389/fpls.2015.00087

Tian, S., Lu, L., Xie, R., Zhang, M., Jernstedt, J. A., Hou, D., et al. (2015). Supplemental macronutrients and microbial fermentation products improve the uptake and transport of foliar applied zinc in sunflower (Helianthus annuus L.) plants. Studies utilizing micro X-ray florescence. *Front. Plant Sci.* 5:808. doi: 10.3389/fpls.2014.00808

Trouvelot, S., Héloir, M. C., Poinssot, B., Gauthier, A., Paris, F., Guillier, C., et al. (2014). Carbohydrates in plant immunity and plant protection: roles and potential application as foliar sprays. *Front. Plant Sci.* 5:592. doi: 10.3389/fpls.2014.00592

Vandenkoornhuyse, P., Quaiser, A., Duhamel, M., Le Van, A., and Dufresne, A. (2015). The importance of the microbiome of the plant holobiont. *New Phytol.* 206, 1196–1206. doi: 10.1111/nph.13312

Vergnes, S., Ladouce, N., Fournier, S., Ferhout, H., Attia, F., and Dumas, B. (2014). Foliar treatments with Gaultheria procumbens essential oil induce defense responses and resistance against a fungal pathogen in *Arabidopsis*. *Front. Plant Sci.* 5:477. doi: 10.3389/fpls.2014.00477

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Biostimulant Discovery and Development using Plant Gene Regulatory Networks

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Introduction

The Mendel technology platform based in Hayward, CA is the foundation of the Koch Biological Solutions vision to deliver targeted, science-based biological products that improve crop productivity. Mendel's core capabilities in analyzing plant gene regulatory networks and executing robust plant physiology experiments has enabled the development of product candidates from our internal discovery pipeline and through in-licensing agreements.

Strategy

Mendel's extensive experience in the identification of plant transcription factors (Riechmann et al., 2000) led to the focused characterization of plant gene regulatory networks (PGRNs) that modulate yield-relevant crop physiological responses (e.g. see Heard et al., 2003; Nelson et al., 2007; Preuss et al., 2012; Rice et al., 2014). Transcriptional profiling studies enabled the identification of diagnostic gene expression fingerprints for PGRNs that are correlated with improved physiological responses such as abiotic (e.g. drought) and biotic (e.g. fungal pathogen) stress tolerance as well as intrinsic yield responses such as elevated photosynthetic capacity. Mendel has used the gene expression fingerprints to create a unique and high-throughput screening platform to identify natural products that improve crop productivity through molecular activity on the underlying PGRN (Armstrong et al., 2001). Coupled with quantitative bioactivity assays and a robust agronomy program, the Mendel platform is yielding biostimulant product candidates with diverse modes of action. In parallel, Mendel is leveraging our staged plant physiology testing pipeline to evaluate products comprising live microbes. These studies will define the factors that influence the activity of these complex products to maximize the value for growers.

Literature Cited

Armstrong, J. I., Holtan, H. E., Ohto, M., Bailey, A. M. "Reporter constructs for compound screening." U.S. Patent 9,322,070, issued April 26, 2016.

Heard, J., Broun, P., Riechmann, J. L., Keddie, J., Pineda, O., Adam, L., Samaha, R., Zhang, J., Yu, G. L., Ratcliffe, O. and Pilgrim, M., 2003. Transgenic plants comprising polynucleotides encoding transcription factors that confer disease tolerance. U.S. Patent 6,664,446.

Nelson, D. E., Repetti, P. P., Adams, T. R., Creelman, R. A., Wu, J., Warner, D. C., Anstrom, D. C., Bensen, R. J., Castiglioni, P. P., Donnarummo, M. G., & Hinchey, B. S. 2007. Plant nuclear factor Y (NF-Y) B subunits confer drought tolerance and lead to improved corn yields on water-limited acres. PNAS. 104:16450-16455.

Rice, E. A., Khandelwal, A., Creelman, R. A., Griffith, C., Ahrens, J. E., Taylor, J. P., Murphy, L. R., Manjunath, S., Thompson, R. L., Lingard, M. J., Back, S. L. 2014. Expression of a truncated ATHB17 protein in maize increases ear weight at silking. PloS one, 9:e94238.

Riechmann, J. L., Heard, J., Martin, G., Reuber, L., Jiang, C. Z., Keddie, J., Adam, L., Pineda, O., Ratcliffe, O. J., Samaha, R.R., Creelman, R., Pilgrim, M., Broun, P., Zhang, J. Z., Ghandehari, D., Sherman, B. K., Yu, G. 2000. Arabidopsis transcription factors: genome-wide comparative analysis among eukaryotes. Science. 290:2105-2110.

Preuss, S. B., Meister, R., Xu, Q., Urwin, C. P., Tripodi, F. A., Screen, S. E., Anil, V. S., Zhu, S., Morrell, J. A., Liu, G., Ratcliffe, O. J., Reuber, L., Khanna, R., Goldman, B. S., Bell, E., Ziegler, T. E., McClerren, A. L., Ruff, T. G., Petracek, M. E. 2012. Expression of the Arabidopsis thaliana BBX32 Gene in Soybean Increases Grain Yield. PLoS one. 7:e30717.

American Society of Agronomy

California Chapter

2017

Session #10

New Ways of Looking at Old Problems: Innovations in agronomic analysis and research.

Session Chair:

Mark Lundy

Using new analytical tools to increase the value of a long-running crop variety-testing program

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Introduction

In 2016, we began an evaluation of the field and analytical methodologies of the University of California small grains variety-testing program, with the goal being to increase the value of the program for its stakeholders via new analytical methods. This presentation demonstrates the application of GGE biplot and mixed linear model methodologies to data from this statewide testing program, discusses the results from these methodologies, and compares these results with historical methods of analysis to illustrate the value of these methodologies.

A basic theoretical framework for crop variety trials

The purpose of a variety-testing program is to generate data to reliably predict the performance of crop varieties within a target production region, with the goal of identifying superior cultivars (IRRI, 2006, Yan, 2014). There are important issues to consider regarding crop variety-testing: 1) Assessing variety performance based on single locations or seasons is unreliable (Yan, 2014), new cultivars must be evaluated over multiple locations and seasons (i.e. a multi-environment trial) (IRRI, 2006, Yan and Hunt, 1998); 2) Genotype-by-environment (G×E) interaction underpins all aspects of crop variety testing (de Leon, et al., 2016), G×E must be considered in the design and analysis of multi-environment trials, and; 3) A group of environments that consistently share the same best cultivar(s) is termed a mega-environment (Yan and Tinker, 2005). Meaningful evaluation of genotypes and variety recommendations can only be conducted within mega-environments (Yan, 2014, Yan, et al., 2015). A target production region may be subdivided into different mega-environments to identify specifically adapted cultivars for each sub-region, which will lead to increased overall productivity for the whole target region (Yan, 2014). Conversely, different target regions may be merged into a single mega-environment if a broadly-adapted cultivar is identified that performs best across a whole target region (Yan, 2014).

Modern analytical methods for crop variety testing

Multiple analytical methods and tools are available for crop variety trial data. In this presentation we focus on two methods – GGE biplots and linear mixed models. We have chosen to utilize these because they offer straightforward, statistically sound, and complimentary methods for the analysis and interpretation of variety trial data (Kempton, 1984, Smith, et al., 2005, Yan, 2014, Yan and Kang, 2003, Yan and Tinker, 2006).

The analytical tool many readers will be familiar with is analysis of variance (ANOVA), and therefore it requires mention here. ANOVA allows for the estimation of variance components and their significance, which are useful for variety testing, but has limitations, especially for exploring G×E effects (Kempton, 1984, Smith, et al., 2005, Yan and Hunt, 1998) because: 1) It requires balance (all varieties in all years and locations) to be valid; 2) It only reports the presence or absence of G×E effects, without providing information regarding temporal or spatial patterns, and; 3) It only reports the significance of G×E effects when the mean of all contrasts is significant and can therefore report a lack of interaction when it in fact exists. ANOVA alone is therefore not an optimal method for analyzing variety trial data or exploring G×E interactions.

Biplots offer a comparatively straightforward method for visualizing the structure of G×E interaction and can be applied to data sets with limited missing data (Kempton, 1984, Yan, 2014, Yan and Kang, 2003, Yan and Tinker, 2006). We refer readers to Yan (2014) for an overview biplot analyses of MET data. A biplot analysis requires a matrix of phenotype values for each genotype (i.e. yield) by environments (i.e. specific locations and/or seasons). The phenotype values can be simple mean values or the output of more complex linear mixed models. A number of computer programs are available for conducting biplot analyses (Laffont, et al., 2013, Wright and Laffont, 2015, Yan and Kang, 2003).

Linear mixed models, as compared to ordinary linear models such as ANOVA, have advantages for analyzing MET data. These advantages include ease with which incomplete data can be handled, the ability to use more realistic within-trial models for error variation (e.g. spatial correlation models), improved means estimates by better ascribing variance to different experimental factors, and the ability to assume some sets of effects (e.g. trial location) to be random rather than fixed (Smith, et al., 2005). Many authors increasingly recommend linear mixed models over simple linear models for the analysis of MET data.

Relating theory to the UC Small Grains program

Historically, the UC small grains variety-testing program has been broadly similar to other crop-testing programs in California, and other states of the US[2], in terms of field methodology, type and extent of data analysis, and reporting of results. The trials comprise approximately 100 cereal varieties that are evaluated at approximately 10 statewide locations. There is a lack of balance between years as new varieties are added and old ones dropped. Individual trials are randomized complete block designs with four replications. In annual reports through 2015, the performance of varieties at individual sites are presented first, then locations are grouped into three sub-regions - the Sacramento, San Joaquin, and Imperial Valleys (**Error! Reference source**

[2] Currently available at http://smallgrains.ucdavis.edu/

not found.). Every year a table similar to Table 1A is presented for every species at every location. Crop performance is summarized using arithmetic means, with coefficient of variation and least significant difference across all varieties given for individual locations.

Table 1: An example of how the field data for the UC Small Grains Program variety-tests has been summarized (the San Joaquin Valley and Imperial Valley data are summarized in a similar way).

A) Single location

Entry	Yield (lbs/acre)	Rank
1340	3270	48
1361	5110	37
1419	5390	32
1424	3190	49
1478	5950	14
…	…	…
1748	5790	21
1749	5800	20
1766	6510	3
1778	5710	26
1795	5890	18
Mean	5450	
CV%	7.35	
LSD	566.	

B) Summary across all Sacramento Valley locations.

Entry	2015	Rank	2014-15	Rank	2013-15	Rank
1340	3360	47	3660	30	3410	28
1361	5430	34	-		-	
1419	5610	32	5450	22	5040	20
1424	3010	49	4580	26	4570	25
1478	5480	33	5290	23	4960	22
…	…	…	…	…	…	…
1729	5090	43	5520	18	5140	18
1730	6590	12	6110	8	5640	11
1731	5340	36	5460	21	5020	21
1748	5240	37	5540	17	5230	14
1749	6940	6	6410	3	5830	4
	5890		5680		5340	

While there is value in data continuity that should not be dismissed, there are several reasons that the historical methods for analyzing and presenting this data should be modified: 1) Making the yield performance of individual varieties for single locations and seasons the primary form of reporting is sub-optimal because it has low predictive power (nevertheless, there is still a need and interest in single location-year data, and even raw data, and this information should be freely available); 2) Whether the Sacramento Valley, San Joaquin Valley, Imperial Valley regions are mega-environments is unknown, therefore summarizing data in this way may be inappropriate or unnecessary; 3) Arithmetic means can be strongly influenced by outliers, or "skewness", in data and therefore other analytical methods may give a better prediction of yield.

Using common wheat yield data from the 2013 through 2016 variety trials conducted in California, biplots to explore G×E were generated with the *gge* package in R (Wright and Laffont, 2015), and models of variety performance were generated using linear mixed models with the *nlme* package (Pinheiro, et al., 2016). Least-squares means were estimated from the mixed models using the *lsmeans* package (Lenth, 2015). For simplicity, the summary data from 2015 and 2016 are presented here.

In the biplots, obtuse angles between regions (i.e. all other regions and the Southern San Joaquin Valley) suggest crossover G×E is present (

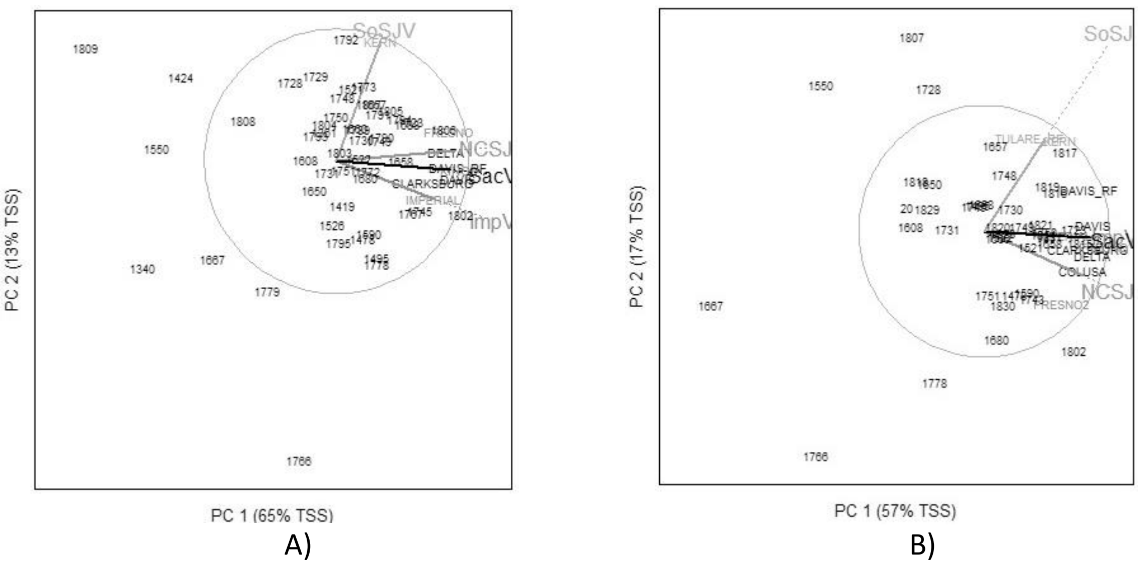
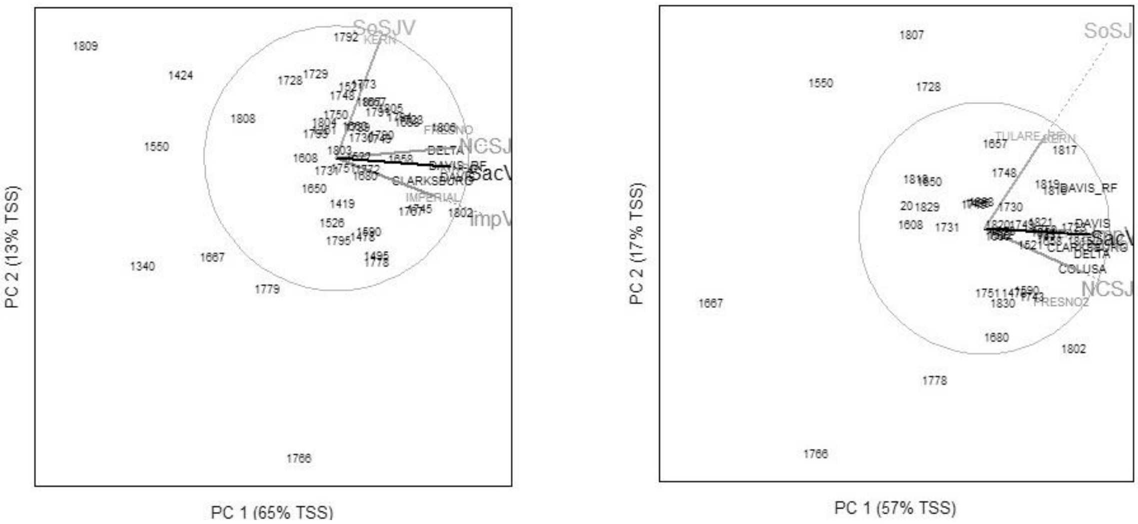


Figure 1). Analysis of data from other years suggests a similar pattern. The size of the G×E effect is low compared to Location and Genotype (~20%), however, which may suggest it is not meaningful in practical terms (Yan, 2014). In ambiguous cases such as this other types of analyses are needed to inform the decision to divide production regions. For example, variance component estimates from an ANOVA (not presented) show the genotype-by-environment to genotype ratio is relatively small (<1) in all years, which indicates that dividing the region may not be justified (Yan, 2014). Inspection of variety yields (not presented) suggests the G×E patterns in the data may be due to a minority of varieties that are not broadly adapted, whilst there are some high yielding and broadly adapted. Given that the current analyses are inconclusive it suggests designing future field trials to better detect these possible mega-environments may be justified, this could include having more sites in the Southern San Joaquin region.

Whilst appropriate regional divisions are presently unclear, the results of the current analysis do clearly show that for common wheat yield in California the historical separation of the data into the Sacramento Valley, San Joaquin Valley and Imperial Valley may not be meaningful since the regional divisions do not correspond with these traditional divisions.

Assuming mega-environments are present, an example of a data summary generated using least-squares means predictions from the linear mixed model, excluding the Southern San Joaquin Valley, is given (

Table 2A). Contrasting this with the historical data summary formats in Table 1 and Table 2B illustrates how the use of GGE biplots and linear models generates simpler and potentially more reliable variety recommendations. The difference in yield predictions and variety rankings is notable.



A) B)

Figure 1: GGE biplots of yield data for A) 2016 and B) 2015 common wheat variety trials in California. Locations grouped by region: SacV – Sacramento Valley, NOSJ – Northern San Joaquin Valley, SOSJV - Southern San Joaquin Valley, IMPV – Imperial Valley.

Table 2: A) An example of how the field data for the state-wide common wheat trials could be summarized, using least-squares means predictions from the linear mixed model informed by the GGE biplot above (the summary excludes the Southern San Joaquin Valley on the assumption it may be a different mega-environment from the other regions) using 2015 and 2016 data. B) The same data summarized using methods similar to those used historically.

A) Predictions from the linear mixed model

ENTRY	Yield (lbs/acre)	Standard Error	Rank
1816	7284	434	1
1750	7139	478	2
1802	7125	478	3
1815	7077	373	4
1658	7035	473	5
…	…	…	…
1807	4772	435	37
1766	4739	386	38
1550	4687	341	39
1728	4540	547	40
1667	3820	404	41

B) Arithmetic means for same region.

Yield (lbs/acre)	Standard Error	Rank
6830	252	7
7526	221	1
6860	75	6
7367	439	3
7409	248	2
…	…	…
4727	271	39
5019	554	36
4868	183	37
4429	382	40
3820	367	41

Conclusions

The purpose of a variety-testing program is to generate data to reliably predict the performance of crop varieties. We are evaluating the University of California Small Grains variety-testing program in the context of the latest science regarding crop variety evaluation, with the goal of increasing the value of the program for its stakeholders. There are several opportunities to increase the value of the UC Small Grains variety trials through the use of new analytical tools. In particular, better trial designs and more reliable and meaningful predictions of variety performance could be achieved by the use of biplot analyses and linear mixed models.

Literature cited

de Leon, N., J.-L. Jannink, J.W. Edwards and S.M. Kaeppler. 2016. Introduction to a special issue on genotype by environment interaction. Crop Science 56: 2081-2089.

IRRI. 2006. Rice Breeding Course http://www.knowledgebank.irri.org/ricebreedingcourse/. International Rice Research Institute.

Kempton, R.A. 1984. The use of biplots in interpreting variety by environment interactions. Journal of Agrcultural Science, Cambridge. 103: 123-135.

Laffont, J.-L., K. Wright and M. Hanafi. 2013. Genotype plus genotype x block of environments biplots. Crop Science 53: 2332-2341.

Lenth, R. 2015. lsmeans: Least-Squares Means. https://CRAN.R-project.org/package=lsmeans.

Pinheiro, J., D. Bates, S. DebRoy and D. Sarkar. 2016. nlme: Linear and Nonlinear Mixed Effects Models. http://CRAN.R-project.org/package=nlme.

Smith, A.B., B.R. Cullis and R. Thompson. 2005. The analysis of crop cultivar breeding and evaluation trials: an overview of current mixed model approaches. Journal of Agricultural Science 143: 449-462.

Wright, K. and J.-L. Laffont. 2015. gge: Genotype Plus Genotype-by-Environment Biplots. R package version 1.0. https://CRAN.R-project.org/package=gge.

Yan, W. 2014. Crop Variety Trials: Data Management and analysis. First Edition ed. John Wiley & Sons, Inc.

Yan, W., J. Frégeau-Reid, R. Martin, D. Pageau and J. Mitchell-Fetch. 2015. How many test location and replications are needed in crop variety trials for a target region? Euphytica 202: 361-372.

Yan, W. and L.A. Hunt. 1998. Genotype by environment interaction and crop yield. Plant Breeding Reviews 16: 135-178.

Yan, W. and M.S. Kang. 2003. GGE Biplot Analysis. A graphical tool for breeders, geneticists, and agronomists.CRC Press, Boca Raton, FL.

Yan, W. and N.A. Tinker. 2005. An intergrated biplot analysis system for displaying, interpreting, and exploring genotype x environment interaction. Crop Science 45: 1004-1016.

Yan, W. and N.A. Tinker. 2006. Biplot analysis of multi-environment trial data: Principles and applications. Canadian Journal of Plant Science 86: 623-645.

Bring the Power of Big Data to Agriculture

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Farmers Business Network (FBN) utilizes data science and machine learning to provide farmer members with unbiased and unique insights about their fields, powered by billions of data points from our network. FBN is building the world's largest agronomic dataset - made up of billions of data points, gathered from sophisticated sensors on farm equipment. We provide farmers with product performance, benchmarking, and predictive analytics based on real world performance data.

Figure 1 demonstrates how big the data we gather at FBN can be used to optimize the selection and placement of seed varieties across farms, and how this method compares to previously-available data sources used for making this decision.

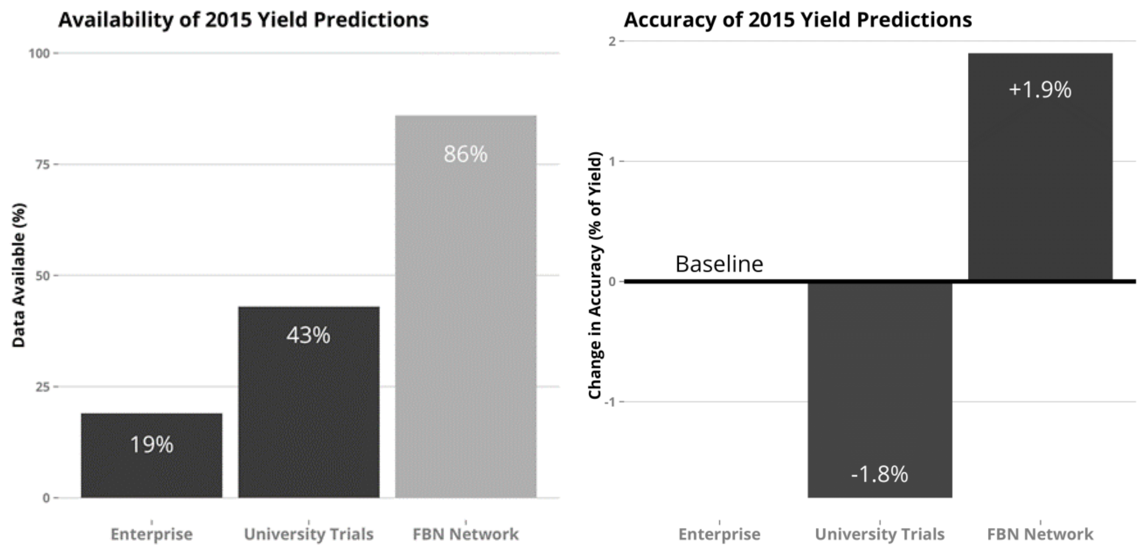

Figure 1. Left: the average percentage of corn varieties on the market for which various data sources provided data. Right: the accuracy of each of those three data sources in predicting corn variety performance in 2015.

Our presentation will discuss this and other benefits of using large, aggregated datasets from commercial farms for optimizing agricultural decision making.

ET-based Site-Specific Moisture Release Curves for Forecasting Both Plant Water Stress and Plant Response to Irrigation Events

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Evapotranspiration (ET) is the process of evaporation from plant and soil surfaces and from within plant tissues (i.e., water movement through stomata). Tule ET sensors are the only technology that can measure the Actual ET from your field. The Tule Actual ET sensor is a hardware device installed in your field above the plant canopy. The hardware device communicates to our server using a cellular connection. Tule reports the amount of water used by your field, your irrigation application amount, a forecast of atmospheric demand, and a recommendation for the amount of water to apply in the coming week based on your production goal.

Actual ET tells you about the field -- not just one point in the soil or just one plant. You manage your ranch field by field, not plant by plant. Actual ET provides information at the scale of your management operations. Actual ET integrates the Soil-Plant-Atmosphere Continuum over a field. The Soil-Plant-Atmosphere Continuum is the movement of water from the soil, through the plant, and into the atmosphere, and eventually returned to the soil as rainfall. If the soil is not supplying enough water, the Actual ET decreases. If the plants close their stomata, the Actual ET decreases. If the air temperature cools, the Actual ET decreases. Actual ET provides the plant water stress level, known as the Plant Response Index (PRI). The PRI normalizes for changes in the weather. A decrease in the PRI means an increase in the water stress level, and correlates with other measures of plant water stress, like leaf water potential.

Actual ET is the amount water that is lost from a field. By knowing the Actual ET, you know how much water you need to apply to replace what the field lost. The Tule dashboard provides irrigation recommendations based on the previous week’s Actual ET and PRI, the forecast atmospheric demand, and our knowledge on the amount of water required to reach various production goals.

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2017 Poster Abstracts

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UNDERGRADUATE STUDENT POSTERS

Edamame Yield and Quality of Soybean Varieties under Organic Conditions

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The Organic Vegetable Project at California State University Farm provides recommendations on vegetables to local growers and the Chico community. Recent trials compared the following seven soybean varieties for edamame production and quality: Midori giant, Kuroshinju, Tokyo black, Tohya, Green legend, Beer Friend, and Butterbean. Edamame refers to the green pods and immature seeds of soybean that are harvested and consumed as a vegetable before the pods turn yellow and the seeds get hard. The varieties were established in a completely randomized trial with 12 replications in an Almendra loam soil in April 2016. The experiment consisted of 84 plots of 1 by 3 meters, each planted with about 380 seeds. Crop stand and days to flowering were recorded. Plants were harvested after about 77 days from seeding date when pods had formed solid seeds. Yield and yield components were recorded, and pod flavor, texture, and color was assessed by total soluble solids to sucrose ratio, hardness, and exact color definition, respectively. Edamame varieties produced a range of 33 to 267 pods plant^{-1} (72 to 462 g pod^{-1} plant^{-1}) from which 18 to 139 pods plant $^{-1}$ (269.4 g pod^{-1} plant^{-1}) were marketable. Among the varieties, Butterbean produced the highest yield (463 g plant^{-1**}) and the largest number of marketable pods (138 pods plant^{-1}). In terms of quality, the greatest flavor score belonged to Kuroshinju, and the best texture score was measured in Green Legend. Overall, Butterbean produced the largest yield, and pods of Green legend had the best quality among the seven varieties under organic conditions in Chico, CA.

Early Assessment of Fababean Germplasm for Yield and Biological Nitrogen Fixation

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Fababean (*Vicia faba*) is one of the oldest field crops that is grown around the world for human food (dry beans and green pods) and animal feed. This cool season legume crop fixes more atmospheric nitrogen (up to 200 kg N ha-1) and adds more N to soil than many legume crops. Most fababean varieties produce large biomass that enhances soil organic matter and suppresses weeds. Because of these characteristics, fababean offers great potentials as a cover crop in California. A fababean genotype variety trial (375 genotypes) has been established at the CSU-Chico Farm to identify genotypes that are suitable as cover crop in northern California. The germplasm was obtained from the Germplasm Resources Information Network, and sown on September 20 and October 20, 2016. Data are being collected to characterize the population for cold resistance, growth habit (determinate and indeterminate), biomass production, days to flowering and pest infestation. Plant genotypes varied markedly in terms of plant height (10 to 67 cm), leaf chlorophyll content (26 to 56 SPAD values), and susceptibility to aphid infestation (132 genotypes were not infested, 108 genotypes were moderately infested and 135 genotypes were severely infested by aphids). Other characteristics of the germplasm are presented and discussed. Important goals of this research are to evaluate these genotypes in terms of biological nitrogen fixation rates, green-pod (edamame) yields, and their usefulness as a cover crop to improve soil fertility in agriculture production systems in California.

Comparing respiration dynamics on row cropped soil using biochar and mushroom compost

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Biochar (a high-carbon, high-porosity, pyrolysis by-product) has received considerable attention over the last decade for its potential as a soil amendment to sequesters C and provide soil health benefits. In the Sacramento Valley, Premier Mushroom generates a high potassium walnut-shell biochar, a by-product of bioenergy production, and a mushroom bedding compost as by-products of their integrated farming operation. This study employed a 10-week in-vitro soil incubation to investigate the effects of these amendments on soil respiration across nine different treatment combinations (treatments: biochar, compost, combinations of biochar and compost, pre-composted biochar and compost (PBC) with application rates of 2.5 & 5 Tonnes/Hectare and a no treatment control). Biochar and compost applications have been shown to alter soil respiration rates (increasing and decreasing). This studies goal was to establish a potential range of conditions for standard application rates of these amendments. All treatments were applied to Almendra loam, collected from the California State University, Chico University Farm. Incubation occurred in pint mason jars at room temperature with soil moisture at field capacity. Results reveal PBC and compost at 5 T/ha produced the greatest increases in soil respiration while biochar at 5 t/ha tracked below the control and orders of magnitude lower than PBC and compost. Data analysis is on-going but preliminary findings clearly demonstrate the diverse effects these organic amendments can have on soil respiration rates. The final components of this project will analysis of N dynamics across this study to better understand implication soil fertility. Although preliminary these results indicate great potential for these amendments to alter soil C dynamics with significant implication when applied at field scales.

Can Walnut shell-based biochar provide potassium to support plant productivity?

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Biochar (a high carbon byproduct of pyrolysis) has received considerable research attention over the last decade as a potentially important soil amendment, contributing to soil quality and long-term soil C storage. Research has demonstrated a variety of benefits to soil physical properties and nutrient dynamics across a broad range of biochars generated from diverse biomass feedstocks. A major barrier to utilizing biochar is demonstrating a linkage between consistent physiochemical properties and agronomic and/or soil quality benefits. In the Sacramento Valley, Premier Mushroom is producing a unique and physiochemically consistent biochar from walnut shells (high porosity, surface area, and ~ 7-9% by mass Potassium content) as a byproduct of bioenergy. Walnut shell biochar has received limited research attention as a soil amendment with none focusing on its role as a local source of potassium to support carrot production. This research evaluates the agronomic benefits of a locally produced walnut biochar, as a soil amendment providing potassium for crop growth and promoting soil quality, in a plot study of carrot production. Carrots are grown for eight weeks in continuously row crop soil collected from the CSU Chico University farm under an experimental design with individual treatments of biochar (2.5 & 5 tonnes/ha) and mushroom compost (2.5 & 5 tonnes/ha) and different combinations of 2.5 and 5 tonnes/ha of each respectively along with a no-amendment control. It was concluded that there was a direct correlation between the increasing rate of applied biochar and compost to larger concentrations of potassium when the soil and carrot flesh were analyzed; therefore biochar and compost may help improve soil potassium fertility. A central goal of this research is to develop an integrated assessment model that quantifies greenhouse gas emissions reductions associated with local amendment utilization and ecosystem services associated with enhanced soil quality.

Identification of potential oomycete plant pathogens from natural waterways in Fresno County to irrigation reservoirs at the University Agricultural Laboratory

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Phytophthora spp. and *Pythium* spp. belong to a class of fungal-like organisms known as oomycetes. Many species in these two genera cause devastating losses to a variety of annual and perennial crops grown in California. Previous research on the University Agricultural Laboratory (UAL) at California State University, Fresno identified a number of known oomycete pathogens from the soil and irrigation reservoirs. The species identified in this survey have been frequently baited from streams in forest ecosystems in California. The goal of this current research was to expand the previous survey and determine a possible source for these oomycetes to enter the irrigation reservoirs at the UAL. Therefore, the objectives were to; 1) bait oomycete plant pathogens from natural waterways supplying Fresno County crops, 2) characterize baited oomycetes to species, and 3) compare species composition identified from natural waterways and the UAL. Oomycetes were detected from water samples using a standard pear baiting technique. Symptomatic pear tissue was excised and plated on PARP medium. Resulting isolates were characterized using direct colony PCR and DNA sequencing of the internal transcribed spacer region. With the exception of *Pythium dissotocum* and *Pythium aphanidermatum* there was little evidence of an overlap in species composition between the natural waterways and the UAL. However, three species recently described as pathogens to pistachio were identified. *Phytophthora parsiana*, *Phytopythium helicoides*, and *Phytophthora* taxon walnut, were detected in several locations that could potentially be transmitted to the UAL through irrigation water.

Comparisons of canopy light interception in almond and walnut orchards using ground, low flying aircraft, and satellite based methods

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Canopy light interception is a main driver of water use and crop yield in almond and walnut production. Fractional green canopy cover (Fc) is a good indicator of light interception and can be estimated remotely from satellite using the normalized difference vegetation index (NDVI) data. Satellite-based Fc estimates could be used to inform crop evapotranspiration models, and hence support improvements in irrigation evaluation and management capabilities. Satellite estimates of Fc in vegetable crops are highly correlated with ground based measurements. The validity of Fc satellite estimates in orchard crops, however, needs to be assessed before incorporating them into irrigation scheduling or other crop water management programs. Landsat-based NDVI and Fc from NASA's Satellite Irrigation Management Support (SIMS) were compared with four estimates of canopy cover: 1. light bar photosynthetically active radiation measurements using a ceptometer, 2. in-situ and image-based dimensional tree-crown analyses, 3. high-resolution NDVI data from low flying aircraft, and 4. orchard photos obtained via Google Earth and processed by an ImageJ thresholding routine. Correlations between the various estimates are discussed.

Effect of Walnut and Pistachio Sap on Spore Germination and Mycelial Growth of *Neofusicoccum mediterraneum*, *Neofusicoccum parvum*, *Phomopsis* (*Nomelini* spp.), and *Diaporthe neothicola* (*Phomopsis neotheicola*)

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Spore suspensions from one isolate of each of Neofusicoccum mediterraneum, Neofusicoccum parvum, Phomopsis (Nomelini spp.), and Diaporthe neothicola (Phomopsis neotheicola) were treated with filtered sap extracted from commercial walnut and pistachio cultivars and spore germination rates were measured. Additionally, filtered sap was applied to 4 mm mycelial plugs and the growth measured after incubation. Pistachio sap increased the mycelial growth of phomopsis, Neofusicoccum parvum, and Neofusicoccum mediterraneum. Walnut sap inhibited the mycelial growth of Diaporthe neotheicola (Phomopsis neotheicola). Walnut sap decreased the spore germination rates of all four isolates tested.

Recruiting Young Students from Underrepresented groups into Agricultural Sciences

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Undergraduate plant science volunteer students of California State University, Fresno (Fresno State) had an opportunity to help educate underrepresented minority (URM) students with the Migrant Institute of Science, Technology, Engineering, and Mathematics (STEM) and Leadership Program. This program is a collaboration between the Fresno State Outreach and Special Programs, and the Education Leadership Foundation of Fresno. The goal of the program is to expose students to science, agriculture, careers and college life. Undergraduate students participated throughout the two-week summer session and educated 89 high school students from the Central Valley region of California. The members presented various lectures in agricultural science and gave hands-on laboratory and field experience. The topics ranged from soil science, including texture, structure, morphology and taxonomy, integrated pest management, pathology, horticulture, agricultural mechanics and careers in agriculture. The students learned about the importance of furthering their education, and the career opportunities available to them in the agricultural industry. Plant science student volunteers identified with the social and educational barriers they face by mentoring them with their own personal stories, knowledge and enthusiasm for agriculture. Students gained a broader understanding of agriculture, career opportunities and the sustainability of our future in agriculture.

Development of validation data sets for a transient hydro-salinity model using EM-38 soil surveys, irrigation water monitoring and forage analysis

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Soil salinity is a major factor affecting irrigated agriculture in today's world, especially in arid/ semi-arid regions like the Western San Joaquin Valley of California. In this region, both salinity and drainage are limiting factors for agriculture. Soil salinity is a very dynamic property both spatially and temporally. Thus, mapping at the field scale requires a rapid and reliable means of taking geospatial measurements. Electromagnetic Induction (EM) survey data and prediction equations relating the apparent electrical conductivity (EC_a) measured by the EM-38 to soil salinity (ECe) are important tools to assess the spatial variability of soil salinity in a field. This research is being conducted at the SJRIP (San Joaquin River Improvement Project) facility managed by Panoche Water District (Los Banos, California) where subsurface drainage water is re-used on ~6,000 acres of dedicated cropland (primarily forages such as 'Jose' tall wheatgrass (*Thinopyrum ponticum* var. 'Jose') and alfalfa (*Medicago sativa*)) to reduce salt loading into the San Joaquin River. EM-38 soil salinity surveys were conducted in two alfalfa and two tall wheatgrass fields to monitor soil salinity in response to the salinity (ECw) and volume of applied drainage water. Soil samples taken to a depth of 120 cm (4 ft.) in 30 cm (1 ft.) increments for calibration of ECa data were analyzed for pH, ECe, gravimetric water content and saturation percentage. The average ECe was 12.5 to 19.5 dS/m (tall wheatgrass) and 9.2 to 14.4 dS/m (alfalfa fields) for spring and fall 2016 sampling. GIS maps were developed depicting the spatial variability of salts in the fields. Data will be used for the refinement and validation of a computer model (CSUID-II) developed as a decision support tool to optimize soil leaching fractions for irrigation water of varying salinity levels, with the overall goal of improving the sustainability of forage production in the SJRIP using saline irrigation.

Influence of Growing Degree Days on Sugarbeet (*Beta vulgaris*) Evapotranspiration and Crop Coefficient

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Knowledge of crop water requirements and crop coefficients is essential when scheduling irrigations using the evapotranspiration-based (ET) method. Such information is also critical to optimize irrigation water applications and improve crop water use efficiency, particularly in periods of drought. Traditionally, crop ET (ET_c) and crop coefficients (K_c) are reported as a function of time during the growing season. However, previous studies conducted on tomato suggested that ET_c and K_c data expressed in terms of Growing Degree Days (GDD) might provide estimates less dependent on location and climatic conditions. We conducted a two-year lysimetric study to develop ET_c and K_c curves for sugarbeets grown under drip irrigation in a clay loam soil. Sugarbeets were planted in the Fall of 2014 and Fall of 2015 at the UC Westside Research and Extension Center in Five Points, CA. Comparative ET_c and K_c curves were developed and reported both as a function of time and GDD. Relationships between K_c and fractional ground cover were also derived for each growing season. Results indicated that seasonal ET_c was 1034 mm and 540 mm for the first and second growing seasons, respectively. Midseason K_c ranged from 1.2 to 1.35 in 2014-15 and from 1 to 1.1 in 2015-16. Daily GDD accumulation varied from 70 to 311 units between seasons. Maximum groundcover was achieved at 186 DAT (2400 GDD units) and 180 DAT (2292 GDD units) in the first and second years, respectively. A strong correlation ($R^2 > 0.88$) between K_c and fractional ground cover was also observed for each growing season.

Root Yield of Drip Irrigated Sugar Beets, an Alternative Fodder Crop

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The dairy and beef cattle industries of California consistently rank in the top four of the state's most valued commodities. It takes a tremendous amount of water to grow the alfalfa, corn, and various forage crops which fuel these thriving industries. Given the uncertainty of the state's water supply, alternative feed crops are currently being tested with the hopes of developing a more sustainable fodder crop rotation. In this research project, sugar beets, or in this case feed beets, were evaluated for both water use efficiency and nitrogen use efficiency when grown under different irrigation and nitrogen regimes. 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 furrow) and nitrogen rate as the sub-treatment (0, 100, 150, 200 lb N/ac). The feed beets were grown in the Central Valley of California in a sandy loam soil located on the campus farm at California State University, Fresno. Data from the first growing season was analyzed to determine which treatments had an effect on root weight. Preliminary results show that irrigation did influence the average root weight per acre ($P<0.05$). The 100% ET drip had a significant increase in root yield compared to both the 70% ET drip and the 100% ET flood method. Nitrogen rates did not have an effect on root weight, but an interaction between irrigation and nitrogen rate was detected ($P=0.053$). The interaction occurred only with the 100% ET drip coupled with the fertilizer control rate of 0 lb N/ac, resulting in slightly diminished root weight averages.

Residual Effects of Pre-plant Herbicides on Transplanted Tomatoes

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Studies were conducted in 2015 and 2016 to evaluate plant injury to simulated residues of some common pre-plant herbicides used in tomato production and other crops rotated with tomatoes. Response of transplanted tomatoes to incremental doses of pre-plant herbicides trifluralin, *s*-metolachlor, and pendimethalin at residual doses of 0, 0.03, 0.06, 0.12, 0.25, and 0.5 ppm were evaluated. One tomato seedling was transplanted in each pot. At 45 days, the plants were clipped at the soil surface and the above- and below-ground parts were separated. Dry weights of all plant parts were recorded. The doses required to reduce biomass by 10% (GR10) and 50% (GR50) were estimated. Trifluralin caused greater reductions in above-ground biomass than pendimethalin and *s*-metolachlor with GR10 and GR50 values of 0.02 and 0.46 ppm, respectively. The GR10 of *S*-metolachlor and pendimethalin were 0.03 and 0.08 ppm, respectively for above-ground biomass. The GR50 for both these herbicides were >0.5 ppm. *s*-metolachlor caused the greatest reductions in root biomass with GR10 and GR50 of 0.004 and 0.22 ppm, respectively. The GR10 values for trifluralin and pendimetalin were approximately 0.008 and 0.04, respectively; whereas, the GR50 for both these herbicides were >0.5 ppm. Stomatal conductance was generally reduced at the higher doses of all herbicides compared to the untreated control. Leaf area was reduced by *s*-metolachlor more than the other herbicides. Although trifluralin caused greater reduction in above-ground biomass, *s*-metolachlor had the greatest overall potential to cause above- and below-ground injury. Pendimethalin was relatively safer than the other two herbicides. Therefore, residual concentrations of herbicides in the soil should be assessed before transplanting tomatoes in buried drip-irrigated fields in California.

Field Performance of 21 Alfalfa (*Medicago sativa*) Varieties under Saline Irrigation: soil salinity, dry matter yield and mineral composition.

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Due to the water shortage in California, saline waters will increasingly be used for irrigation, in particular for forage production. Alfalfa is ranked as moderately sensitive to salinity (Mass and Grattan, 1999), with a published threshold for yield loss of 2 dS/m ECe (soil salinity). Twenty new alfalfa varieties, bred for salinity tolerance, and CUF-101 (public control) were tested in an experiment in clay loam soil at West Side Research and Extension Center, in Five Points, CA. Two irrigation water salinity levels, low salinity (EC_w 1.1 to 1.6 dS/m) and high salinity (EC_w 8-10 dS/m) were applied to challenge the alfalfa varieties. During the first two years of saline irrigation (i.e. 2015 and 2016), the relative yield (RY=HS/LS) averaged 86.6% and 89.3%, respectively, indicating yield penalties of only 11-13% in soil salinities averaging 10.6 and 16.5 dS/ ECe, in May and October, respectively (0-90 cm soil depth. These soil salinities far surpass those considerable for alfalfa production. Five varieties emerged with notably higher yields under saline irrigation; however, the coefficient of variation was very high for the yield data, especially under HS irrigation and it was determined that secondary problems resulting from the saline-sodic irrigation, i.e. soil crusting, reduced infiltration and non-infiltration influenced the variety performance, possibly as much as the salinity *per se*. Shoot potassium/sodium (K/Na) ratios, a common indicator of salt tolerance ranged from 2.5 to 3.34 in 2016, but a strong correlation between shoot K/Na and shoot dry matter yield was not observed. Soil salinity maps were created to understand the spatial and temporal accumulation of salts in the soil profile.

Temperature, Glyphosate Interactions within Roundup Ready Alfalfa

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The intermountain region of northern California is known for its high-value alfalfa (*Medicago sativa* L.) forage production systems, attributed to cold night time temperatures and short growing season. Many farmers in this region prefer Roundup Ready varieties because of the ease of weed management and subsequent opportunity to maximize forage quality. In 2014 and 2015 crop injury was observed in several fields in Scott Valley, Siskiyou County following early-spring applications of glyphosate. Anecdotal evidence and results of several field experiments suggested a correlation between glyphosate application and the timing of the next frost event. To support the field research, a series of greenhouse trials were conducted at UC-Davis to determine if similar injury symptoms could be recreated under more controlled conditions. Greenhouse trials encompassed several parameters including duration and intensity of frost event, time between frost event and herbicide application, plant height, and stand age. Injury symptoms, including chlorosis, leaf curling and shoot necrosis, have prevailed more frequently with treatments combinations that include frost events, 2 hours of 0℃, occurring within 24 hours of a herbicide application on plants 12” or taller. Damage was not uniform across all replicates in each treatment, and was variable even within the injured plants themselves. Injury occasionally prolonged for several weeks, but ideal greenhouse growing conditions allowed for quick regrowth of curled leaves and chlorotic shoots. Additional research needs to be conducted to better understand the conditions necessary to reproduce injury symptoms, and to determine the underlying physiological causes of crop damage seen in the field.

Nitrogen Mineralization Potential in California Agricultural Soils

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To date, little data has been compiled in regard to net nitrogen mineralization (N_{min}) potential in California agricultural systems. Given the environmental and economic impacts associated with over application of nitrogen (N) fertilizers, it is essential to generate accurate predictions on N_{min} rates as this process can be a significant source of N. The goals of this study were to assess a temperature response of N_{min} across a variety of mineral and organic soils throughout Central and Northern California and relate N_{min} to soil properties. Undisturbed soil cores (radius = 2.25 cm x height = 14 cm) were sampled pre-planting in the spring of 2016 from the topsoil from 30 sites within 7 regions. Cores were incubated at 5 °C, 15 ° C, and 25 °C for 10 weeks and maintained at 60 % water filled pore space throughout the experiment. Soils were selected that had not recently been amended with manure/compost nor had been cover cropped. Results revealed an exponential increase in mineralization with temperature in all but four soils. At 25 °C, N_{min} ranged from 10.48 mg kg^{-1} to 128.34 mg kg^{-1}. N_{min} was significantly higher in soils with higher organic matter from the Delta and Tulelake basin at 15 °C and 25 °C compared to soils from the Central and Salinas Valley. Stepwise multivariate regression yielded preliminary results indicating that total carbon, total nitrogen, and particulate organic matter nitrogen served as the best predictors for N_{min}.

Potassium Availability and Fixation in California Rice Fields

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Rice productivity in the Sacramento Valley has historically been high, but yield growth has slowed in recent years. One important factor related to limits to rice productivity is soil potassium (K). As the soils in this area have historically been high in K, growers have not needed to apply it to their fields. However, after years of harvest without K replenishment, growers are beginning to observe K deficiencies. In attempts to correct them by supplying the soil with K fertilizers, growers are seeing little or no response from the crop. The reason for this lack of response to K amendments is likely K fixation, in which K ions are trapped in between soil particle interlayers and unavailable to plants. Preliminary data of soils sampled in rice fields across the Sacramento Valley shows that there is no clear relationship between a field's K budget and the extractable potassium in the soil or with the amount of K in the plant tissues, indicating that there is likely K fixation occurring. Preliminary data also shows that soils low in exchangeable K are also frequently K-fixing soils. The distribution of K fixation in the Sacramento Valley is suspected to be related to soil mineralogy, as the two sides of the valley have distinct mineral compositions, each with different K fixation capacities. Soil mineralogical analysis will help to elucidate the relationship between soil mineralogy and available soil potassium. Data from lab analyses and web soil survey will allow us to understand which areas are likely to have K fixation. Better understanding the relationship between soil type and K dynamics will help growers better manage their fertility and increase yields.

Optimizing protocols for measuring harvested dry matter of silage crops on California dairies

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Accurate quantification of harvested dry matter (DM) of silage crops is required for dairy producers to comply with water quality regulations and generate reliable feed inventories. The objectives of this study were to establish the accuracy of common protocols for measuring harvested DM of silage crops and identify protocols that are both practical and accurate. The harvested DM from 3 corn fields and 3 winter forage fields was measured by weighing and sampling every truckload from each field. Each truck sample was analyzed individually for DM content and multiplied by the respective load weight to calculate each truck's delivered DM weight. The truck DM weights were summed over each field to calculate harvested DM. To simulate practical sampling protocols, estimates of harvested DM were calculated by repeatedly subsampling from each full dataset randomly, at even time intervals, or consecutively. All estimates using the same protocol were summarized with 95% confidence intervals and compared to the calculated harvested DM. Among studied harvests, a maximum of ten random samples was required to bring the 95% confidence interval of the estimated harvested DM within ±10% of the calculated harvested DM. If one random truckload was weighed and sampled, the mean width of the confidence interval was 40% compared to 12% with 10 truckloads. Sampling at even time intervals improved accuracy over random sampling while consecutive sampling reduced accuracy on all farms; the mean confidence interval width for random, even interval, and consecutive sampling protocols was 12%, 8%, and 16%, respectively, when at least 10 samples were taken. This study demonstrates the improvement in accuracy from weighing and sampling more truckloads, spaced evenly throughout harvest.

Short-lived effects of walnut shell biochar in a long-term field experiment

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Short-term effects of biochar applications on soil fertility and plant productivity have been well studied, but meta-analyses and reviews on this topic continually note the lack of experiments investigating biochars' effects over multiple seasons and call for validation of mesocosm results in field studies. Our objective was to investigate the effects of a high temperature (900 °C) walnut shell (WS) biochar on crop yields and soil nutrient cycling and availability over four seasons in a field experiment. Previously, this WS biochar was found to increase net nitrification rates in a short-term mesocosm experiment; therefore, we hypothesized that each year, plots with biochar would have higher NO_3^--N concentrations early in the growing season, but lower concentrations late in the season due to increased losses, causing negative effects on crop yields due to decreased N availability. Long-term biochar plots were established at UC Davis's Russell Ranch Sustainable Agricultural Research Facility and are farmed using typical commercial practices. The 2x2 factorial design tests the WS biochar (vs. a control) with both mineral fertilizer and compost. Biochar was applied once in 2012 at a rate of 10 t ha^{-1}, and fertilizers were applied yearly a typical rates for the annual rotation of tomato and corn systems. Crop yields and soil nutrients were measured over four years. WS biochar had an effect only in 2013, one year after biochar application, when it increased corn yields by ~8% in both fertilizer systems and increased exchangeable K^+, PO_4-P, and Ca^{2+}. Inorganic N pools were not significantly affected by the biochar in any season. WS biochar has a delayed yet short-lived effect on plant-available nutrient concentrations and crop productivity.

Response of Walnuts to Simulated Drift of Rice Herbicides

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English walnut is one of the top commodities grown in California and its importance has been increasing in the last decade, with a gross dollar value of $1.36 billion in 2012. In the Sacramento Valley, walnut orchards often are in close proximity to rice fields. Therefore, herbicide applied to rice may drift on walnuts and cause injury. The majority of rice herbicide applications are made by airplane between the end of May and early July. This time frame coincides with a period of rapid growth for walnut trees and flower bud initiation for the subsequent year's crop. Two simulated herbicide drift field studies were established at the UC Davis research station to evaluate symptoms and growth effects of rice herbicides on young walnut trees. In the first study, the effect of three commonly used rice herbicides were studied: bispyribac, bensulfuron and propanil. Each herbicide was applied at four simulated drift rates: 0.5%, 1%, 3% and 10% of the use rate in rice. All herbicides caused significant damage and delayed growth of young walnut leaves and shoots with the maximum symptoms observed 28 days after treatment. At one month after treatments, walnuts started recovering, although symptoms were still evident in late October. In a separate study, bispyribac was applied four times at weekly intervals at two different rates: 0.5% and 3% of the rice use rate. Bispyribac, at both rates, caused significant symptoms to walnut leaves and growth delay of young shoots. Symptoms were still readily observed in late October, more than four months after the last simulated drift event. The effects of these treatments on walnut yield and quality are being evaluated in ongoing experiments.

PROFESSIONAL (NON-STUDENT) POSTERS

Effects of Biochar Amendment and Fertilizer Sources on Serrano Chili Pepper Yield, Uptake, and Nitrogen Fate

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Efficient nitrogen (N) management strategies are a key approach in addressing the increase of food demand and environmental protection. Failing to achieve adequate nitrogen use efficiency (NUE) in agricultural systems can cause damaging outcomes including degradative water quality, increase in greenhouse gas emissions and economic loss. Understanding balanced and appropriate uses of inorganic and organic nitrogen fertilizers can improve NUE, increase overall crop yield and preserve environmental quality. The objective of this research is to determine the effectiveness of biochar amendment and nitrogen fertilizer sources on NUE improvement in serrano pepper production. A field pot experiment was conducted with treatments of biochar amendments and various combinations of inorganic and organic N fertilizers. Although the first year data did not show significant differences in pepper yield, biochar amendment and incorporation of organic N at lower ratio appeared to increase total plant N uptake. During the growing season, NH_3 volatilization increased after fertilization events, but with lower or delayed peaks from organic N. Nitrous oxide production was reduced in soil profile from both biochar amendment and organic N source. We continue this study to determine the long term benefits of N source and soil amendment for crop production.

Effects of nitrogen fertility and irrigation level on yield and quality of corn and sorghum forages in the San Joaquin Valley

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In 2016, we evaluated the effects of nitrogen fertility and irrigation levels in several forage corns and sorghums at two sites in Fresno County. Irrigation treatments ranged from 50% ETc of corn to 100% ETc of corn. N fertilization treatments ranged from 0 lbs N/acre supplemented in-season to 300 lbs N/acre applied in season. At one site, the Kearney Ag Research and Extension Center (KAREC), plots were furrow irrigated and nitrogen top-dressed as urea. At the other site, the West Side Research and Extension Center (WSREC), we fertilized and irrigated the plots using a sub-surface drip irrigation (SDI) system. At KAREC, neither irrigation, nor N fertility, nor their interactions had direct, significant effects on yield. However, irrigation level and cultivar had significant effects on lodging percentage ($p < 0.002$). Higher levels of irrigation increased lodging, and lodging of several sorghum varieties was significantly more sensitive to irrigation ($p = 0.007$). Although the interaction was not significant ($p = 0.053$), there was an apparent effect N fertility between cultivars on lodging. As N fertility increased, lodging decreased for two sorghum varieties and increased for another. Corn yield and lodging were relatively stable under all treatments. Plant population and yield was significantly correlated to lodging. One regression analysis demonstrated that as lodging increased, yield significantly decreased ($p < 0.001$, $R^2 = 0.14$). Another regression analysis revealed that as plant population increased, lodging significantly increased ($p < 0.001$, $R^2 = 0.41$). It appeared that the greatest effect of fertility and irrigation on yield was related more to the effect of those variables on lodging. Data collected from WSREC and analyses of soil and forage quality are still being analyzed.

Determining seasonal differences in crop water requirements using growing degree days for processing tomato

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California leads in the production of processing tomatoes in the U.S., most of which is concentrated in the Central Valley where irrigation provides the primary and often only water supply. Given the extent of tomato production in the state and its reliance on irrigation, it is critical to accurately estimate the crop water requirements (CWR) to optimize water applications and improve water use efficiency. CWR are most accurately determined through measurements of crop evapotranspiration (ET_c) using precision weighing lysimeters. ET_c generated by lysimeters can then be used to develop precise crop coefficients (K_c) that are needed for irrigation scheduling. Studies have suggested that K_c can be influenced by crop varieties and that expressing K_c as a function of growing degree days (GDD) can account for the climatic conditions of a specific growing season (heat units). Therefore, the objectives of this study were to: 1) determine the seasonal differences in ET_c and K_c for processing tomato (*Lycopersicon esculentum*) grown over a three-year period; and 2) develop ET_c and K_c curves as a function of both time and GDD. The study was conducted at the UC Westside Research and Extension Center lysimeter facilities in Five Points, CA. The results indicated that seasonal ET_c amounted to 598 mm, 463 mm, and 407 mm in years 1, 2, and 3, respectively. Midseason K_c was slightly above 1.2 in year 1 and ranged from 0.75 to 0.88 in years 2-3. Daily GDD accumulation varied from 73 to 136 heat units among years. Maximum canopy cover was achieved at 84 DAT (1206 GDD units), 118 DAT (1638 GDD units), and 106 DAT (1434 GDD units) in years 1, 2, and 3, respectively.

Updating Information on Water Use of Pistachio Orchards Grown in the San Joaquin Valley of California on Increasingly Saline Soils

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Pistachio acreage in California is rapidly expanding thanks to good profitability of this crop and its capacity to grow and produce in salt-affected soils. Our team is developing updated information on actual water use (ET) of mature pistachio orchards grown on saline soils under micro-irrigation methods. Actual Evapotranspiration (ETa) and Crop Coefficients (Ka) were determined for the 2015 and 2016 seasons on 3 orchards grown in the San Joaquin Valley (SJV) on grounds with increasing levels of soil-water salinity using the residual of energy balance method with a combination of eddy covariance and surface renewal equipment. Tree canopy cover, light interception, and plant water status across the orchards were also measured and evaluated. Our preliminary results show that salinity strongly affects the tree water use, resulting in 10-30% less ET for medium to high salt-affected soils. Salinity also showed a strong effect on tree water status and light interception, as suggested by values of the Midday Stem Water Potential (Ψ_{SWP}) 10 to 15-bar lower in salt-affected than in the control orchard, and by intercepted Photosynthetic Active Radiation (PAR) decreasing from 75% in the control orchard to 25% in the severely salt affected grounds.

The Ka values we observed in this study are lower than those commonly used for irrigation scheduling in the SJV, suggesting that pistachio growers could better tailor irrigation management to the actual site-specific orchard conditions (e.g. canopy features and soil-water salinity) if they are provided updated information. Improved irrigation practices could likely lead to water savings of 10-15 ac-in/ac and thus improve the resource-efficiency and competitiveness of pistachio production in the SJV.

Keywords: *Pistacia vera* L., salinity, stem water potential, surface renewal, canopy cover.

Southern San Joaquin Valley (Tulare Lake Basin) Management Practices Evaluation Program

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The SSJV MPEP is a multi-year program to identify, evaluate, and increase adoption of management practices protective of groundwater as required under the Region 5 Irrigated Lands General Order. A committee of water quality coalitions is implementing the MPEP in a three-part approach: Identify known protective practices and refine those practices as new information is gathered. Existing knowledge will be collected from industry, public sector expertise, literature, and growers. Technical partners will help with focused field studies, as necessary. Share protective practices with growers. Priority will be given to practices that growers can readily use and that have greatest potential to protect groundwater quality, and to leveraging the broad range of existing information-sharing resources. Assess implementation of protective practices and verify their protectiveness. The Soil and Water Assessment Tool (SWAT) will be calibrated to represent SSJV farming conditions. Verification will be informed by data from ILRP-required reports. Several resources will be developed including: new information relevant to implementation of NRCS practice standards; yield-to-nitrogen-removed conversions for the majority of crops in the Central Valley; outreach materials and events for producers and their advisors about protective practices; SWAT refinements posted to the Committee website; collection and web publication of producer-oriented resources for minimizing loss of applied nitrogen to groundwater; an online decision-support tool, informed by SWAT simulations, to help growers visualize effects of alternative suites of management practices in the producer's unique climatic, soil, crop type, and topographic setting. Technical partners include USDA-NRCS, UC, CDFA, and CSU.

Response of Alfalfa to Nitrogen Fertilization under Saline Conditions

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Abstract

Nitrogen fertilization can have a negative effect on root nodulation of alfalfa and thus the fixation of atmospheric N is limited. However, under saline conditions, or where root growth is compromised, N fertilization of alfalfa may be beneficial. A greenhouse experiment was conducted to evaluate the effect of N fertilization on alfalfa growth, root nodulation and N fixation under saline conditions. Salinity was induced to soil salinities (EC_e) of 0.73, 5.69, 9.86 and 15.3 dS/m using solutions of $CaCl_2$ and NaCl. N^{15}-labelled NH_4NO_3 was added at 30, 60 and 120 ppm. A control treatment (no added N) was also considered. Pots were filled with 4 kg soil (60% sand: 40% sandy loam). Alfalfa shoot dry weight and number of nodules were determined over 3 cuts, taken at 4 week intervals.
Soil salinity had a negative effect on alfalfa parameters. Relative to the lowest salinity treatment (0.73 dS/m), cumulative shoot dry matter (DM) decreased by approximately 11%, 24% and 36% at 5.69, 9.86 and 15.3 dS/m EC_e, respectively. Increasing soil salinity also resulted in a consistent reduction in nodule number.

Addition of N significantly increased shoot DM. Compared to the control, addition of 30 and 60 ppm N (~ 17 and 34 lbs. N/acre) increased cumulative shoot DM by approximately 16 and 34% at 0.73 and 5.69 dS/m, respectively, whereas at 9.86 and 15.3 dS/m the increase reached 22-41 and 41-73%, respectively. Increasing N addition from 60 to 120 ppm further increased the cumulative yield at soil salinity treatments up to 9.86 dS/m, but it had a slight negative effect on cumulative yield at 15.3 dS/m. Although increasing N addition increased the number of root nodules, the highest number of nodules was counted under the lowest salinity treatment.

Data indicates efficiency of N fertilization on alfalfa growth under saline conditions, but the significance of N fertilization is more pronounced at soil salinities (EC_e) in the range of 9.86-15.3 dS/m. These salinities are far above the published salinity tolerance threshold for alfalfa (2.0 dS/m EC_e), but recent work by our group, as well as by Cornacchione and Suarez (Crop Science, 2015), indicate that a threshold closer to 6.0 dS/m EC_e may be more appropriate.

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