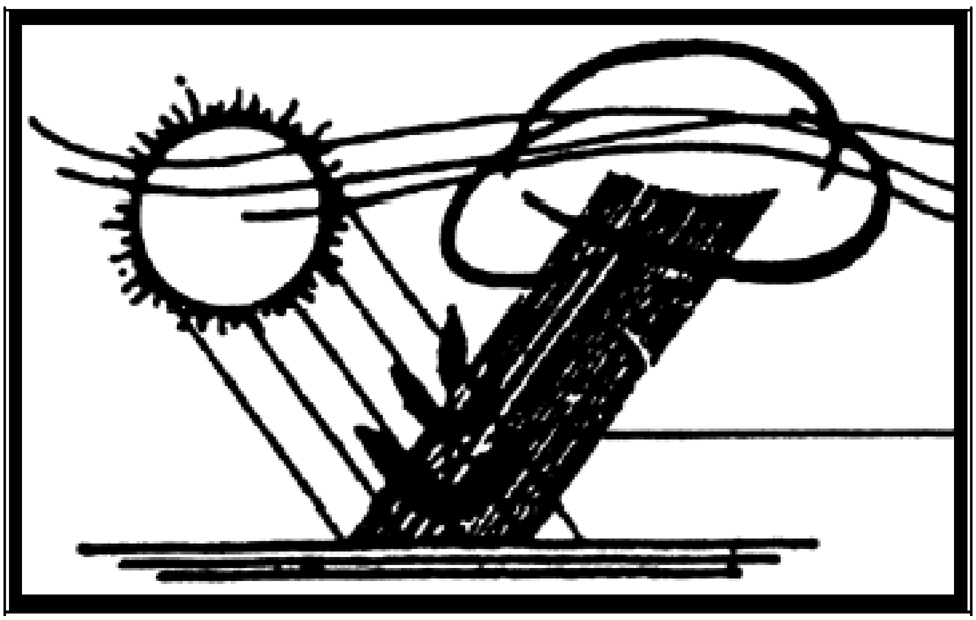
CONFERENCE PROCEEDINGS

2007
California Plant and Soil Conference

Opportunities for California Agriculture



California Chapter of the American Society of Agronomy

Co-sponsored by the California Plant Health Association

February 6 & 7, 2007

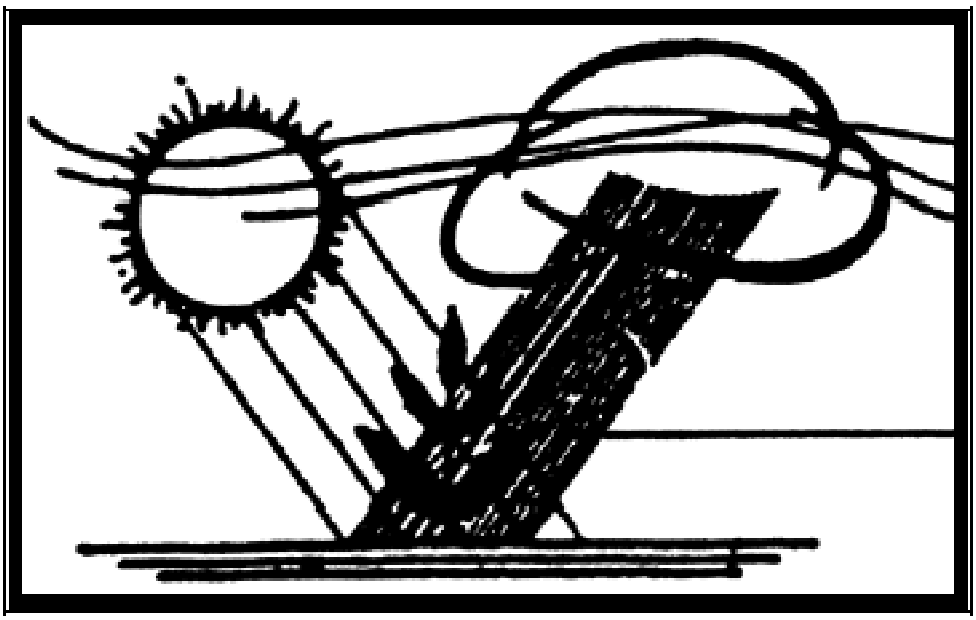
Radisson Hotel
500 Leisure Lane
Sacramento, CA 95815

To download additional copies of the proceedings or learn about the activities of the California Chapter of the American Society of Agronomy, visit the Chapter's web site at: http://calasa.ucdavis.edu

CONFERENCE PROCEEDINGS

2007
California Plant and Soil Conference

Opportunities for California Agriculture



California Chapter of the American Society of Agronomy

Co-sponsored by the California Plant Health Association

February 6 & 7, 2007

Radisson Hotel
500 Leisure Lane
Sacramento, CA 95815

To download additional copies of the proceedings or learn about the activities of the California Chapter of the American Society of Agronomy, visit the Chapter's web site at: http://calasa.ucdavis.edu

CALIFORNIA PLANT & SOIL CONFERENCE
OPPORTUNITIES FOR CALIFORNIA AGRICULTURE

TUESDAY, FEBRUARY 6, 2007

10:00 **General Session Introduction** – Session Chair & Chapter President - Will Horwath**,** LAWR, UCD

10:10 **Future of Biofuels in the Portfolio of California Agriculture –** A. G. Kawamura, California Department of Food and Agriculture

10:40 **Potential Agricultural Crops and Wastes for Bioenergy –** Brian Jenkins, University of California, Davis

11:10 **Markets for Bioenergy Crops –** Bill Jones, Pacific Ethanol, Fresno California

11:40 Discussion

12:00 **Western Plant Health Association Luncheon Speaker:** Renee Pinel, President - Western Plant Health Association, "Government & Agriculture: A Forecast Forward"

CONCURRENT SESSIONS (PM)

I. AGRICULTURE AND WATER QUALITY – PROGRAMS AND INVESTIGATIONS

1:30 Introduction – Session Chairs: **Mary Bianchi**, UCCE**,** SLO County, **Allan Fulton,** UCCE, Tehama County, **Al Vargas**, CA Dept, of Food and Agriculture

1:40 **Why is Irrigated Agriculture Regulated for Water Quality** – Pamela Creedon, Executive Officer, CVRWQCB

2:00 **Current and Developing Water Quality Regulatory Programs in the Central Valley** – Rudy Schnagl, CVRWQCB

2:20 **Impacts of Pyrethroid Pesticides on Water Quality from Urban and Agricultural Sectors** – Dr. Don Weston, Professor, Dept. of Integrative Biology, UC Berkeley

2:40 Discussion **3:00 BREAK**

3:20 **Integrated Pest Management Tools and Resources for Protecting Water** – Dr. Mary Louise Flint, UC IPM, University of California

3:40 **Management Options to Reduce Pyrethroid Pesticides in Tailwater from Row Crops** – Allan Fulton, UCCE Farm Advisor, Tehama, Glenn, Colusa, and Shasta Counties

4:00 **A Perspective on Monitoring Potential Ground Water Impacts in Farming Operations** – Dr. Thomas Harter, UC Extension Specialist, Hydrology, LAWR, UC Davis

4:20 Discussion

4:30 **ADJOURN**

II. NUTRITIONAL DEVELOPMENT OF TREE, VINE, TOMATO & ORGANIC RICE CROPS

1:30 Introduction – Session Chairs: **Rob Mikkelsen**, Potash & Phosphate Institute; **Ben Nydam,** Dellavalle Laboratory Inc.

1:40 **Is There a Biological Rationale for Foliar Fertilizers and Biostimulants in Tree Production?** – Dr. Patrick Brown, Professor of Plant Nutrition, UC Davis

2:00 **Improving the Nutrient Efficiency of Tree Fruits** – Franz Niederholzer, Orchard Systems Farm Advisor, UCCE, Sutter & Yuba Counties

2:20 **Improving the Nutrient Efficiency of Processing Tomatoes** – Tim Hartz, Vegetable Crops Specialist, UC Davis

2:40 Discussion **3:00 BREAK**

3:20 **Rootstock Influence on Grapevine Nutrition and Minimizing Nutrient Losses to the Environment** – Dr. Jim Wolpert, Department of Viticulture & Enology, UC Davis

3:40 **The Importance of Phosphorus Nutrition for Maintaining Vineyard Production and Fruit Quality Levels** – Dr. Paul Skinner, Terra Spase, Inc.

4:00 **Organic Rice Farming Nutrition – A Growers Perspective** – Lundberg Rice Farms

4:20 Discussion

4:30 **ADJOURN**

ADJOURN to a Wine and Cheese Reception *in the Poster Room.*

A complimentary drink coupon is included in your registration packet.

WEDNESDAY, FEBRUARY 7, 2007

CONCURRENT SESSIONS (AM)

III. INNOVATION AND IMPORTANT ISSUES IN PEST MANAGEMENT

8:30 **Introduction** – Session Chairs: **Tom Babb**, CA Dept. of Pesticide Reg.; **Suduan Gao**, USDA-ARS

8:40 **Urban IPM Opportunities** – Karey Windbiel-Rojas, UC Statewide IPM Program

9:00 **Options to Reduce VOC Emissions from Pesticides** – Randy Sagawa, CDPR

9:20 **Methods to Reduce Fumigation Volatilization Losses from Agricultural Fields** – Husein Ajwa, Dept. of Plant Science, UC Davis

9:40 Discussion

10:00 BREAK

10:20 **Managing Vine Mealybug and GWSS** – Lucia Varela, UCCE, Area IPM Advisor – North Coast

10:40 **Lodi Rules – Sustainable Pest Management Practices** – Cliff Ohmart, Lodi Woodbridge Wine grape Commission

11:00 **Realities of Pesticide Risks in Agriculture** – Carl Winter, Department of Food Science and Technology, UC Davis

11:20 Discussion

IV. WHAT IS IN THE IRRIGATION TOOLBOX?

8:30 **Introduction** – Session Chairs: **Blake Sanden**, UCCE, Kern County, **Charles Krauter**, CSU Fresno

8:40 **Estimating Crop ET using CIMIS and New ET Studies** – Rick Snyder, UCD Biometeorology Specialists

9:00 **Smart Water Applied Technology in Landscape Irrigation: Is Ag. Next? –** David Zoldoske, CSU Fresno

9:20 **Commercial Applications of Soil Moisture Technology for Production Ag** – Western Farm Service staff, Keith Backman – Dellavalle Laboratory, Inc., Doug Stanley - Irrometer

9:40 Discussion

10:00 BREAK

10:20 **New Ideas for Fertigation** – Jerome Pier, Western Farm Service, Modesto

10:40 **Maintaining and Optimizing Drip Systems** – Larry Schwankle, UCCE Irrigation Specialist, Kearney Ag. Center

11:00 **Using EQIP Cost Share Dollars to Improve Irrigation Systems & Management** – Bob Fry, CA State Water Resources

11:20 Discussion

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

CONCURRENT SESSIONS (PM)

V. Transition/Diversification

1:30 **Introduction –** Session Chairs: **Jeff Wong,** Cal Poly SLO; **David Woodruff,** Woodruff Ag Consulting

1:40 2007 Farm Bill Specialty Crop Policy Options and Consequences: A California Perspective **– Jay Noel, California Institute for the Study of Specialty Crops/College of Ag. Cal Poly State University**

2:00 Adaptation of the California Rice Industry in Response to Environmentally Driven Issues **– Chris Greer, UCCE, Colusa County**

2:20 **Current Opportunities in the California Olive Oil Industry – Paul Vossen, UCCE, Sonoma and Marin Counties**

2:40 **Overview of the California Fig Industry and New Interest in Varieties for Fresh Fruit –** Ed Stover, USDA, ARS, Natl. Clonal Germplasm Repository

3:00 Discussion

3:20 <u>**ADJOURN**</u>

VI. Energy Conservation Strategies

1:30 Introduction **– Session Chairs:** Will Horwath, **LAWR, UCD;** Bruce Roberts, **CSU Fresno**

1:40 **Creating Certifiable, Tradable Emissions Reduction Credits: How They Could Be Used in a Cap and Trade Program** – Mike McCormick, Policy Director, California Climate Action Registry

2:00 Evaluating Opportunities for Biofuel Production in No-Tillage Systems **– Jeff Mitchell, UCCE, Kearney Ag. Center**

2:20 **On Farm Experience with Biofuels** – John Diener, Red Rock Ranch

2:40 **Demonstrating Financial Benefits as Catalyst for Adoption of Conservation Technologies** – Allen Dusualt, Sustainable Conservation, SF, CA

3:00 Discussion

3:20 <u>**ADJOURN**</u>

Table of Contents

Session III. Innovation and Important Issues in Pest Management

Session IV. What is in the Irrigation Toolbox?

Session V. Transition/Diversification

Session VI. Energy Conservation Strategies

Poster Abstracts

California Chapter of American Society of Agronomy

Past Presidents

Year	President
1972	Duanne S. Mikkelson
1973	Iver Johnson
1974	Parker E. Pratt
1975	Malcolm H. McVickar
1975	Oscar E. Lorenz
1976	Donald L. Smith
1977	R. Merton Love
1978	Stephen T. Cockerham
1979	Roy L. Branson
1980	George R. Hawkes
1981	Harry P. Karle
1982	Carl Spiva
1983	Kent Tyler
1984	Dick Thorup
1985	Burl Meek
1986	G. Stuart Pettygrove
1987	William L. Hagan
1988	Gaylord P. Patten
1989	Nat B. Dellavalle
1990	Carol Frate
1991	Dennis J. Larson
1992	Roland D. Meyer
1993	Albert E. Ludwick
1994	Brock Taylor
1995	Jim Oster
1996	Dennis Westcot
1997	Terry Smith
1998	Shannon Mueller
1999	D. William Rains
2000	Robert Dixon
2001	Steve Kaffka
2002	Dave Zoldoske
2003	Casey Walsh Cady
2004	Ronald Brase
2005	Bruce Roberts

California Chapter of American Society of Agronomy

Past Honorees

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

California Chapter
American Society of Agronomy

2006 Chapter Board Members

Executive Committee

President William Horwath, Dept. of Land, Air & Water Resources, UC Davis
First Vice President Ben Nydam, Dellavalle Laboratory, Inc.
Second Vice President Tom Babb, CA Dept. Pesticide Regulations
Secretary-Treasurer Joe Fabry, Fabry Ag Consulting
Past President Bruce Roberts, Plant Science Dept. CSU Fresno

Governing Board Members

One-year term	Mary Bianchi, UCCE San Luis Obispo County Allan Fulton, UCCE, Tehama County Jeffrey Wong, Cal Poly State University
Two-year term	Charles Krauter, CSU Fresno Al Vargas, CA Dept. Food & AG Dave Woodruff, Woodruff Ag Consulting
Three-year term	Suduan Gao, USDA - ARS Blake Sanden, UCCE, Kern County Robert Mikkelsen, Potash & Phosphate Institute
Advisor	Casey Walsh Cady, California Dept of Food and Agriculture

2007 Honorees

Norman MacGillivray

William Pruitt

J.D. (Jim) Oster

Norman MacGillivray

Norman MacGillivray was born and raised on the west side of the San Joaquin Valley. He attended elementary school in the two-room Rising Sun Elementary School, then graduated from Patterson High School. Norm served his country as a member of the U.S. Army Occupation Force in Japan. After his honorable discharge from the military, Norm attended the University of California at Davis, graduating in 1951 with a Bachelor of Science degree in Irrigation Science.

Norm's first job after graduating from U.C. Davis was to help organize the irrigation/water districts being formed to provide services from the U.S. Bureau of Reclamation's newly developed Delta-Mendota canal.

Following this assignment, Norm was hired as an irrigation engineer/soil scientist with the USDA Agricultural Research Service. His first task was to evaluate surface irrigation methods and the potential for improvements to current methods. Norm's mentor was Harry F. Blaney, co-developer of the Blaney-Criddle Equation for estimating crop consumptive use. Throughout his career, Norm also served as a professional mentor to a generation of new irrigation scientists.

In the late 1950's Norm was recruited by John Shannon of the California State Department of Water Resources to develop a field program to determine crop consumptive use. That original short-term assignment stretched on for 33 more years.

The field program was based upon soil moisture measurements derived from the use of neutron technology. Norm was an early pioneer in the calibration and use of this new technology. His work included constructing portable sampling platforms to permit accurate sampling without disturbing surrounding vegetation or compacting soil around the sampling points. Norm's attention to accuracy and detail insured that field plot irrigations were managed to avoid deep percolation from the measured profiles.

In the 1980's Norm spent time in China lecturing on irrigation studies conducted in California. He later hosted employees of the Chinese Ministry of Water Development during their visits to California.

Norm MacGillivray was the principle author of the California State Department of Water Resources Bulletin 113-3. This publication, known as the "Cornerstone" of vegetative water-use studies in California, has been the foundation for crop water use estimates throughout the state.

Norm has been married to Martha for more than 50 years, raising 4 children and currently enjoying 5 grandchildren.

Mr. William O. Pruitt

Department of Land, Air, and Water Resources, University of California, Davis
Lecturer and Irrigation Engineer, (Emeritus), Consultant, Agricultural Meteorology
Honorary Member of American Society of Civil Engineers

Agricultural Engineering, Washington State College, 1940-42
Aeronautical Engineering, University of Washington, 1942-44
USNR Midshipman School, Notre Dame University, 1944

B.S., Agricultural Engineering, State College of Washington, Pullman, 1949
M.S., Agricultural Engineering, State College of Washington, Pullman, 1951

HONORS

Washington State University Alumni Achievement Award, 1986
American Society of Civil Engineers (ASCE) Royce J. Tipton Award, 1987
California Irrigation Institute "man of the Year" Award, 1987
Sydney University, New South Wales, Australia Pawlett Fellow, 1985
ASCE, Elected to grade of Honorary Member, 1993

Mr. William "Bill" Pruitt in one of the world's leading authorities on crop/plant-water use efficiency and evapotranspiration. Bill is world renown for his scientific research and has set world standards for measurement and estimation of evapotranspiration and crop water needs.

Author or co-author on some 130 papers and reports on radiation and energy balances, sensible heat and mass transfers above vegetation surfaces, evapotranspiration, irrigation water requirements, and irrigation scheduling procedures. Early studies at Washington State's Irrigation Experiment Station at Prosser, and follow-up work at UC Davis, provided refinement of the Pan evaporation method. Later Pruitt made major contributions in major bulletins on water requirements (University of California, ASCE, and The United Nations Food and Agriculture Organization [FAO]), Included in the FAO reports, are methods developed for estimating reference-crop evapotranspiration and the ET of numerous crops grown under a wide range of conditions.

He has served as a consultant at many universities and research institutes around the world, including those in Lebanon, Israel, Cyprus, Italy, Pakistan, The Philippines, Egypt, and India. He is thankful to God for his parents, who were early 1900s teachers in The Philippines and passed along to their son a strong interest in world travel; also for his wife Ada of 62 plus years, who has served as a wonderful planner, guide and companion during their many travels. The blessing of having four children, ten grandchildren, and three great-grandchildren is respectfully acknowledged as well.

J.D. (Jim) Oster

Emeritus Specialist and Adjunct Professor at the Department of Environmental Science of the University of California, Riverside USA

J.D. (Jim) Oster was born and raised on a farm in Western North Dakota and obtained a BS in Soil Science from North Dakota State University, and M.S. and Ph.D. degrees from Purdue in Soil Chemistry with minors in Inorganic and Physical Chemistry.

Work history includes 2 years in the U.S. Army Chemical Corps, 16 years as a Soil Scientist for the USDA-ARS at the U.S. Salinity Laboratory in Riverside and 19 years as a Soil and Water Specialist for the University of California Cooperative Extension Service at Riverside.

Principal contributions to California Agriculture involve work with soil and water salinity and their impacts on crop production. Doctor Oster's important and critical contributions include the following:

1. Development and tests of soil chemistry models that describe the effects of water content, soil mineral dissolution, exchange reactions, partial pressure of carbon dioxide, and salt concentration and composition on electrical conductivity and exchangeable ion composition. Understanding these effects help us better manage soil and water resources.

2. Summarized and published data, obtained by another researcher, which characterized the effects of irrigation water salinity on water infiltration rates into cropped soils.

3. Lead a UC Committee effort to review and report the effects of soil and water chemistry on infiltration that resulted in a published report as well as an Extension Manual entitled Water Penetration Problems in California Soils.

4. Participated in field research projects while working for ARS and for the University that dealt with water and salinity management using lateral move sprinkler, and surface and Sub-surface drip irrigation systems on avocado, citrus, corn, alfalfa, cotton, and cantaloupe.

5. Dealt with using saline sodic drainage waters for irrigation of Bermuda grass and Eucalyptus trees in sequential water use systems with the objective to reduce drainage volumes generated by irrigated agriculture

An underlying objective of these projects was to test and demonstrate that with good management it was possible to increase the fraction of applied water that was used by the crop and to reduce the fraction that became drainage water requiring disposal.

Jim's work did not stop at California's borders. Review articles, published since 1982, dealt with gypsum usage in irrigated agriculture, irrigation with poor quality water, reclamation of saline and sodic soils, and agricultural management and bioremediation of sodic soils. These reviews and published research papers include coauthors from Australia, Chile, Egypt, India, Israel, Pakistan, and The Netherlands, in addition to many coworkers from the United States.

Jim has unselfishly helped scientific workers from various countries publish their work. He has been an Associate Editor of the journal *AGRICULTURAL WATER MANAGMENT* since 1998 and he became joint Editor-in-Chief in 2003.

He has provided leadership by being the Chairperson of the American Society of Agronomy Committee on the adoption of SI Units, Chairperson of the University of California Committee of Consultants on drainage reduction, and Project Coordinator for the Board on Science and Technology for International Development of soil and water projects funded in Pakistan. He was the president of the California Chapter of the American Society of Agronomy and has been.

Being named a Fellow of the American Society of Agronomy is his most coveted award.

Activities since His April 1, 2000 retirement include two ongoing field-research projects with U.C. researchers: the effects of applied water and its salinity on avocado yields, and drainage water reuse for crop production in on-farm irrigation management systems for the purpose of drainage volume reduction and generation of additional profits. Other ongoing work is with a Resource Economist from California State University, Fresno on regulatory and institutional opportunities to foster the disposal of salt generated by irrigated agriculture within the region where it is generated. Consulting activities, which began after retirement from the University of California, are related to setting water quality standards for salinity and sodicity of irrigation water, utilization of sodium bicarbonate waters for supplementary irrigation of pastures, and irrigation and management of native grass species to reduce wind erosion and dust storms of an inland, dry-lake basin on Seems like he picked April Fools Day to retire for good reason.

Jim has and has had a life beyond research, consulting and writing. He and his wife Karen are in the process of restoring a 1928 Dodge Victory 6, 5-passenger coupe, which was originally owned by Karen's mother. He has also been a transport pilot for the Nevada wing of the Civil Air Patrol and sings in the Riverside Chorale. He and Karen befriended a neighbor who had no family and cared for her in her last years. Married to Karen since 1958, they have three children and five grandchildren. They split their time between homes in Riverside and Greale California.

2007 Scholarship Recipient and Essay

Essay question:

What is the role of biofuels in the future of California agriculture?

Scholarship Committee:

Casey Walsh Cady
Mary Bianchi
Suduan Gao
Robert Fry
Ben Nydam

2007 Winning Scholarship Essay

Monica Galli
California State University, Chico

Biofuels and California Agriculture

Biofuels will play a huge rule in the future of California agriculture. Biofuels, like ethanol made from corn, are renewable fuels derived from biomass. In my opinion, biofuels' mainstream acceptance will start with the agriculture industry. California has always been a leader in adopting new technologies. Currently, the United States is addicted to dwindling foreign oil supplies. California reportedly used 18 billion gallons of gasoline and diesel in 2004 (1). As prices keep rising consumers are becoming aware of fuel alternatives. This year 900 million gallons of biodiesel were used in California, but only five percent were produced in California (2).

In order to become more sustainable, environmentally friendly, and self-sufficient changes must be made that will lead the general population away from petroleum-based fuels supplies. In 2006 Governor Arnold Schwarzenegger signed executive order S-06-06, which raised ethanol production goals for California. The goal is that by 2050, 75 percent of all biofuels used in state will have been produced in the state (2). This means that California is going to invest money towards developing biofuel refinery stations within the state. This executive order has the potential to shift crop production in California. Farmers may choose between food and fuel when planting fields in the future. The plantings of seed crops will definitely increase. Certainly, Central California cotton producers will be greatly affected. Cotton seeds can have high oil content, which makes them a good source of biofuel.

Gas prices can only rise so high before they start to effect production decisions, if biofuels can be priced competitively with traditional fuels than they will be successful. The government will play an important role in the economic feasibility of biofuels. Subsidies may be necessary to make biofuels economically feasible. California agriculture will be a leader in the future of biofuels.

1. *Expanding Opportunities for Biofuels.* Biofuels Workshop and Trade Show Western and Pacific Region. 26 Oct 2004. 5 Dec 2006. <www.energy.ca.gov/papers/2004-10-26_KEESE_BIOFUELS.PDF.>
2. *California Wants Biofuels Production to Be Within the State.* Democratic Energy. 10 May 2006. 5 Dec 2006. <http://www.newrules.org/de/archieves/000113.html>.

Session I

Agriculture and Water Quality Programs and Investigations

Session Chairs:

Mary Bianchi, UCCE, San Luis Obispo County

Allen Fulton, UCCE, Tehama County

Al Vargas, CA Dept. of Food and Agriculture

Why Is Irrigated Agriculture Regulated for Water Quality?

Pamela Creedon

Executive Officer, Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive, #200, Rancho Cordova, CA 95670.

All materials for Pamela Creedon should be sent to: Kiran Lanfranchi–Rizzardi, Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive, #200, Rancho Cordova, CA 95670. Phone: (916) 464-4839. klanfranchi-rizzardi@waterboards.ca.gov

Introduction

A change in the Water Code that went into effect in 2000 required the Regional Water Quality Control Boards (Water Boards) to reassess all programs that had conditional waivers of Waste Discharge Requirements (WDRs). All waivers would sunset on 1 January 2003 if the Water Board did not act. This prompted a review of the waivers that applied to discharges from irrigated lands, which include irrigation return flows and storm water runoff. In addition to the change in the Water Code, the Central Valley Water Board received a petition signed by representatives of several organizations requesting the immediate rescission of the waivers and the adoption of WDRs for discharges from irrigated lands.

The petition claimed that the waiver was no longer supported by current available data and was inconsistent with the California Water Code. Much of the data mentioned in the petition was collected by agencies, including the Central Valley Water Board. The data showed that many water bodies were impaired due to pesticides and other constituents, many originating from irrigated agriculture.

Agricultural activities affect water quality in a number of ways. Surface discharges from irrigated agriculture include fertilizers, a wide variety of pesticides, including diazinon, chlorpyrifos and pyrethroids, copper and other metals, salt, and trace elements such as selenium, and boron, sediment and nutrients.

Actions Taken

On 23 November 2002, the Central Valley Water Board executed an interagency agreement with UC Davis to evaluate the quality of water in agricultural drains throughout the Central Valley. The UC Davis Aquatic Toxicology Laboratory conducted the initial sampling but since December 2003 the work has been conducted by the UC Davis John Muir Institute of the Environment and the California Department of Fish and Game.

On 11 July 2003 the Central Valley Water Board adopted Resolution No. R5-2003-0105, which set forth two conditional waivers of WDRs for irrigated agriculture. One waiver applies to owners and operators of irrigated lands who participate in an approved coalition group that addresses program compliance on a regional basis. The second waiver applies to individual owners and operators who do not or cannot participate in a watershed or sub-watershed coalition effort. Farmers still have the option of complying with the Water Code by submitting a Report of Waste Discharge and receiving WDRs . The action was appealed to the State Water Resources

Control Board (State Board) and taken to Superior Court. It has been upheld with minor changes.

The Central Valley Water Board recognizes that this is a major new program that is still under development. Some of the new activities have included the 2004 formation of a Technical Issues Committee with members from universities, technical consultants, other State agencies, coalition groups and other interested parties, to discuss and provide technical input on issues pertaining to monitoring and reporting activities required under the Irrigated Lands Conditional Waiver Program. Also, a Public Advisory Committee was formed to receive comments from the public on the development of the program.

In May 2004, the SWRCB adopted the Nonpoint Source Implementation and Enforcement Policy, which identified the five key elements that are required for nonpoint source pollution control programs. This Policy brought clarity and direction to the approach that must be taken in the regulation of irrigated lands.

In July 2005 a contract was signed with Jones and Stokes Associates to prepare an Environmental Impact Report for the Irrigated Lands Program. In February 2006, Jones and Stokes Associates completed the draft Central Valley Existing Conditions Report, which discussed the current regulatory setting, surface water conditions, and ground water conditions within the Sacramento, San Joaquin, and Tulare Lake Basins.

The waiver was renewed during the summer of 2006, with some changes, which included its adoption by the Central Valley Water Board as a Board Order, rather than a Resolution. Additionally, growers were given a deadline of 31 December 2006 to join a coalition. The penalty of not doing so could result in compliance being required via WDRs, or as an individual discharger under the Conditional Waiver, in addition to other enforcement actions.

The Central Valley Water Board staff is also preparing a revision to the existing Monitoring and Reporting Program (MRP), which will be presented to the Central Valley Water Board at the June 2007 meeting. In the process of developing the revision to the Coalition Group MRP, staff is utilizing the Technical Issues Committee to provide recommendations on technical issues associated with the existing MRP.

What Have We Learned

Coalition groups have the advantage of developing their own monitoring plans, although they must meet minimum requirements that are described in the MRP and must be approved by the Executive Officer of the Central Valley Water Board. This allows the groups to tailor their plans to their specific areas and each coalition has their own monitoring crew. Currently the groups have finished Phase I (toxicity testing the first two years) of the monitoring and most have completed their first irrigation season of Phase II monitoring, which includes pesticides, nutrients, metals, and other general water quality parameters. Results from the Coalitions' Phase II monitoring will be submitted to the Central Valley Water Board in the near future.

Monitoring conducted from 2004 to 2005, (including Central Valley Water Board monitoring through UC Davis) found detectable levels in about 5% of the 19,000 individual pesticide analyses conducted on surface waters. Of these detections, about 37% exceeded water quality limits.

The results of water column toxicity tests indicate that on a Region-wide basis about 13% of the samples exhibited toxicity. Many of the sampling sites were chosen where there is a high likelihood of agricultural pollution, so these results are not typical of all waters in the Region.

Sediment pesticide analyses have been conducted by UC Davis for the Central Valley Water Board. The results for monitoring conducted in 2004 indicated that about 15% of the tests showed pesticide detections, which included DDT and DDT breakdown products, as well as currently used pesticides such as chlorpyrifos and pyrethroids.

Sediment toxicity tests have been also conducted by both UC Davis and by the Coalitions. The different coalitions report that from 0% to 48% of the sediment samples were toxic to test organisms. However, the Region-wide values range from 27% based on UC Davis results to 42% based on data from the coalitions (Lopez-Read, 2006). Initial studies from UC Davis indicates that approximately 80% of this sediment toxicity is being caused by pyrethroids. Again, sediment sampling sites are not typical of the entire Region.

Agricultural Water Quality vs. Urban Water Quality

Throughout the Central Valley, drains carry both agricultural and urban storm water. Since the start of the Irrigated Lands program, agricultural representatives have asked about efforts being made to control pollution from urban sources.

In urban and suburban areas, storm drains carry large amounts of runoff to nearby waterways. The runoff carries pollutants such as sediment, oil, pesticides, nutrients, heavy metals, and thermal pollution from dark impervious surfaces such as streets and rooftops (EPA 841-F-03-003). These pollutants affect water quality and its beneficial uses.

In the 1990's the Municipal Separate Storm Sewer System (MS4) Program was adopted to regulate nonpoint source pollution from urban areas. In the beginning, known as Phase I, only communities with 100,000 or more people were regulated. In 2002 the program entered Phase II and is now regulating communities with over 10,000 people.

The National Pollutant Discharge Elimination System (NPDES) permits for MS4s are comprehensive and complex. Permit requirements include: storm water has to be treated during development of an area; permittees must do public outreach on storm water pollution prevention; effectiveness of best management practices must be measured; water quality based programs such as a mercury plan or pesticide plan must be developed; monitoring for water quality and toxicity must be conducted.

For more information about the Irrigated Lands Program, visit the Central Valley Water Board's Web site at http://www.waterboards.ca.gov/centralvalley/.

Literature Cited

Lopez-Read, Margie. 2006. PowerPoint Presentation.

EPA 841-F-03-003. Protecting Water Quality from Urban Runoff.

RWQCBCVR. 2001. A Review of Options for Controlling Discharges from Irrigated Lands: Irrigation Return Water; Storm Water Runoff.

Current and Developing Water Quality Regulatory Programs in the Central Valley

Rudy Schnagl

Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive, #200, Rancho Cordova, CA 95670. Phone: (916) 464-4701, Fax: (916) 464-4800.
rschnagl@waterboards.ca.gov

Introduction

The Central Valley Regional Water Quality Control Board (Central Valley Water Board) has been implementing agricultural programs since the agency was established in 1969. There are four major programs addressing water quality issues specifically related to irrigation return waters. Other programs, such as the Confined Animal Regulatory Program, the Total Maximum Daily Load Program and the effort to develop a Salinity Management Plan also address the impacts of agricultural operations.

Rice Pesticide Control Program

During the early 1980's pesticides discharged from Sacramento Valley rice fields caused fish kills in drains and taste complaints regarding the City of Sacramento's drinking water supply. The Board has worked with the state's pesticide regulatory agency (Department of Pesticide Regulation), the rice industry, and numerous other organizations to develop methods to control these discharges. In 1990, the Board adopted a conditional prohibition of discharge for irrigation return flows containing five specific pesticides commonly used on rice fields. This prohibition is waived if the discharger is following management practices approved by the Board. The rice program goes before the Board every year for approval (RWQCB 2001).

Selenium Control Program

In the mid-1980's, selenium levels in subsurface agricultural drainage from the Grassland watershed were determined to be a threat to waterfowl in the wetland areas. A control program adopted in 1988 stressed the use of improved irrigation efficiency to reduce selenium discharges. The program was updated in 1996 to require Waste Discharge Requirements (WDRs) for the control of selenium. WDRs for the Grassland Bypass Project, which serves approximately 97,000 acres of irrigation agricultural land, were adopted in 1998. Farmers are on a time schedule to reduce the selenium loads discharged from this project (RWQCB, 2001).

Evaporation Basins

Agricultural evaporation basins are utilized in the Tulare Lake Basin for the disposal of saline drainwater. Between 1972 and 1985, twenty-eight evaporation ponds were constructed covering a surface area of about 7,000 acres. Presently, 10 ponds with a total surface area of about 4,900 acres are active and managed by seven operators. The remainder have been voluntarily deactivated due to the high costs of mitigation measures. Some have been closed due to toxic effects to water birds from selenium present in the impounded waters (RWQCB, 2001).

Irrigated Lands Program

In July 2003 the Central Valley Water Board adopted two conditional waivers of WDRs. One waiver applies to owners and operators of irrigated lands who participate in an approved coalition group that addresses program compliance on a regional basis. The second waiver applies to individual owners and operators who do not or cannot participate in a watershed or sub-watershed coalition effort. This program calls for monitoring to evaluate the quality of irrigation return flows and the development and implementation of management practices to ensure that water quality objectives are met.

Total Maximum Daily Load (TMDL) Programs

TMDLs are required under a section 303(d) of the Federal Clean Water Act for all impaired surface water bodies. The Central Valley Water Board has listed several water bodies as impaired due to pesticides and other constituents found in agricultural return flows. A TMDL report is prepared to quantify the impact and evaluate the control options available to the Central Valley Water Board. In each case, the reports form the basis of a proposed Basin Plan Amendment report covering the regulatory options and recommended mechanisms for controlling these pollutants. (RWQCB, 2001).

Diazinon and Chlorpyrifos TMDLs

Monitoring since the early 1990s by State and federal agencies and other groups, has confirmed the presence of diazinon and chlorpyrifos at levels of concern in numerous Central Valley waterways. Both agricultural and urban sources have been documented. Agriculture has been the dominant source, since in 2004 the U.S. Environmental Protection Agency banned the sale of all non-agricultural uses of diazinon and most non-agricultural uses of chlorpyrifos (CVRWQCB, 2005).

On 16 October 2003 the Central Valley Water Board adopted a diazinon TMDL for the Sacramento and Feather Rivers. Elevated concentrations of diazinon are observed in January and February, which corresponds to the dormant spray application periods for orchard crops such as almonds, peaches, and dried plums (RWQCBCVR, 2003).

On 21 October 2005 the Central Valley Water Board adopted a Basin Plan amendment for the control of diazinon and chlorpyrifos runoff into the lower San Joaquin River. The primary sources of the pesticides are from orchards and fields. Dormant season sprays that occur in the winter months, generally from December through February, are carried to surface waters by stormwater runoff. Irrigation season sprays that occur in the summer months, generally from March through September, are carried to surface waters by irrigation flows from agricultural fields (CVRWQCB, 2005).

On 23 June 2006 the Central Valley Water Board adopted a Basin Plan amendment for control of diazinon and chlorpyrifos runoff into the Sacramento-San Joaquin Delta. In the last 30 years a decline in the zooplankton community has been observed in the Sacramento-San Joaquin Delta Waterways. Pesticides are one of the factors believed to be responsible for impairment in the Sacramento-San Joaquin Delta Waterways (CVRWQCB, 2006).

Salt and Boron TMDL

On 10 September 2004 the Central Valley Water Board adopted a salt and boron TMDL in the lower San Joaquin River. Importation of irrigation water supplies from the Delta via the Delta-Mendota Canal is recognized as the major source of salt, but agricultural tile drainage and groundwater accretions are major in-basin contributors. Currently, water managers in the basin are looking at real-time management of salt and boron where discharges to the San Joaquin River can be increased in times of high flows.

Nutrient TMDL

On 23 June 2006 the Central Valley Water Board adopted a nutrient TMDL for Clear Lake. Studies indicated that Clear Lake is impaired due to excess nutrients, primarily phosphorus. The excess phosphorus contributes to the occurrence of nuisance blooms of blue-green algae in the lake during the spring, summer, and fall seasons. Most sources of phosphorus are sediment driven and include erosion from agricultural and urban areas, instream channel erosion, timber harvesting, runoff from roads, construction, gravel mining, wildfires, control burns, off highway vehicle use, and dredging and filling. Fertilizer use (both urban and rural) and sewer and septic overflows may also contribute phosphorus to the lake (CVRWQCB, 2006).

Other Programs

Salinity Management Plan

The Central Valley Water Board has joined the State Water Resources Control Board in developing a Salinity Management Plan for the surface waters and groundwaters of the Central Valley. The outcome of this planning effort, which is expected to take eight to 10 years, will be amendments to the Water Quality Control Plans that address all Central Valley waters. Implementation of the plan will take decades. A Central Valley Salinity Policy Group has been established and subcommittees will begin working on various aspects of the project in early 2007. As part of the project, economists at University of California, Davis are evaluating the socioeconomic impacts if salt is not managed (the no project alternative). The California State University, Fresno Foundation and the University of California, Davis are also compiling existing data to identify data gaps and prepare for modeling efforts. Additional information on this program is available at: http://www.waterboards.ca.gov/centralvalley/cv-salts/index.html.

Confined Animal Facilities

General waste discharge requirements are being prepared for all existing milk cow dairies in the Central Valley. The tentative Order, which was sent out for public comment in November 2006, calls for development of nutrient management plans that will reduce the movement of nutrients and other constituents to surface water and groundwater. The dairies would have several years to develop the plan and implement changes needed to fully comply. Consideration of approval of this Order is expected to occur during the spring of 2007.

Additional information is available at:
http://www.waterboards.ca.gov/centralvalley/available_documents/index.html#confined

Literature Cited

CVRWQCB. 2006. Amendment to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Nutrients in Clear Lake.

RWQCBCVR. 2001. A Review of Options for Controlling Discharges from Irrigated Lands: Irrigation Return Water; Storm Water Runoff.

RWQCBCVR. 2003. Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Orchard Pesticide Runoff and Diazinon Runoff into the Sacramento and Feather Rivers Final Staff Report.

RWQCBCVR. 2005. Amendments to the Water Quality Control Plan For the Sacramento

Impacts of Pyrethroid Pesticides on Water Quality from Urban and Agricultural Sectors

Donald Weston
Department of Integrative Biology, University of California Berkeley
3060 Valley Life Sciences Bldg, Berkeley, CA 94720-3140
Phone (510) 665-3421, Fax (510) 665-6729, dweston@berkeley.edu

Introduction

Pyrethroid insecticides have been used in agriculture for decades, with approximately 300,000 lb being used annually in California agriculture since at least the mid-1990s. They have also been used in urban settings for many years, though their use has increased dramatically in the past few years as they replace some of the organophosphate insecticides that have been withdrawn from the marketplace. Yet in spite of long and widespread use, there was, until recently, very little data on their concentrations in the environment. In the first geographically broad study, most agricultural waterways throughout California were found to contain residues of pyrethroids, at times exceeding concentrations toxic to sensitive aquatic life (Weston et al., 2004). Subsequent urban studies (Weston et al., 2005;2006; Amweg et al., 2006) have shown similar conditions in urban creeks. With about 200 agricultural sediment samples and about 100 samples from urban sites, we are now able to develop a detailed picture on the occurrence of pyrethroid residues in the environment and their potential for toxicity.

Agricultural findings

Of 200 sediment samples from agriculture-affected waterways of California's Central Valley collected between 2002 and 2006, 27% caused acute toxicity to Hyalella azteca, a crustacean used nationally to test the toxicity of freshwater sediments. The frequency of toxicity was greater (41% of sites) in small, unnamed agricultural drains that typically serve only one or a few farms, presumably because they are closer to the points of pesticide application. Larger water bodies like creeks and rivers, with a more regional watershed, typically showed toxicity at about one-quarter of the sites.

In the majority of cases when exposure to sediments caused mortality to H. azteca, pyrethroid pesticides were present in sufficient concentration to explain the toxicity (Amweg et al., 2005). Sixty-one percent of the samples exhibiting toxicity had concentrations of pyrethroids sufficiently high that toxicity to H. azteca would have been expected. Bifenthrin (trade names = Capture or Brigade) was the pyrethroid most often responsible for the toxicity. One out of six sites sampled in the Central Valley contained enough bifenthrin to be toxic to H. azteca. Of secondary importance was the pyrethroid lambda-cyhalothrin (trade names = Warrior or Karate), which reached toxic concentrations at 9% of the sites. Chlorpyrifos, an organophosphate insecticide, was the next most important compound in explaining toxicity, with acutely toxic concentrations reached in 8% of the sites. It is interesting that organochlorine pesticides, most of which have not been used for 20-30 years, were present in nearly every sample collected (especially DDT and its degradates). However, concentrations were consistently below toxic thresholds, and in not a single one of the toxic samples was the toxicity believed to be due to organochlorines.

Urban findings

Contrary to popular perception, non-agricultural use of pyrethroids far exceeds agricultural use, at least in California, one of the few areas where data are available. A similar situation is likely elsewhere where there is substantial urban development. Whereas agricultural use of pyrethroids in California is about 300,000 lb/yr, non-agricultural commercial use (mostly applications done by professional pest control firms) is currently about 700,000 lb/yr. Retail sales to homeowners are not included in this non-agricultural figure, but are probably about another 100,000 lb/yr. Some of the major urban uses of pyrethroids include cypermethrin and permethrin for termite control, permethrin to maintain landscaping, and bifenthrin and cyfluthrin for a variety of pests around homes.

Our sampling has been done primarily in creeks draining urban areas of Sacramento, Salinas, and the San Francisco Bay area of California (Weston et al., 2005; 2006; Amweg et al., 2006). After collection of about 100 samples from 21 creeks, we have yet to find fine-grained sediment from an urban creek that do not contain measurable levels of pyrethroids. About two-thirds of the samples showed toxicity to H. azteca, and in nearly every one of these cases, concentrations of pyrethroids in these samples were at levels expected to be toxic.

Just as was the case in agricultural water bodies, in the urban creeks studied the pyrethroid that was most often responsible for the toxicity was bifenthrin. It remains unclear whether the dominance of bifenthrin is due to a particular use of the compound that is prone to transport of residues via landscape irrigation or stormwater runoff, or if it reflects a greater environmental persistence of the compound. Secondarily, the pyrethroids cypermethrin and cyfluthrin also contributed to toxicity in a substantial numbers of samples.

Conclusions

Pyrethroids have traditionally been considered both safer for humans and safer for the environment than the organophosphates they have replaced. While toxicity in the water column, that has been repeatedly linked to organophosphates is rarely a significant issue with pyrethroids, it is clear that because of their tendency to bind to sediment particles, sediment toxicity remains a significant concern. At least in California, the only state where extensive sampling has been done, the compounds are clearly moving in to surface water bodies from areas of both agricultural and urban uses. Urban water bodies often have higher concentrations of pyrethroids and more frequent sediment toxicity than do agricultural water bodies, though in terms of the number and length of waterways affected, agriculture may surpasses urban pyrethroid sources, at least in California on a statewide basis. The strong tendency for pyrethroids to bind to sediment particles suggests the potential for impact mitigation by control of sediment loss, and several efforts are currently underway to explore such practices.

Literature cited

Amweg, E.L., Weston, D.P., Ureda, N.M. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environ. Toxicol. Chem. 24:966-972 (with erratum in 24:1300-1301).

Amweg, E.L., Weston, D.P, You, J., Lydy, M.J. 2006. Pyrethroid insecticides and sediment toxicity in urban creeks from California and Tennessee. Environ. Sci. Technol. 40:1700-1706.

Weston, D.P., You, J., Lydy, M.J. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environ. Sci. Technol. 38:2752-2759.

Weston, D.P., R.W. Holmes, J. You, Lydy, M.J. 2005. Aquatic toxicity due to residential use of pyrethroid insecticides. Environ. Sci. Technol. 39:9778-9784.

Weston, D.P., Amweg, E.L., Mekebri, A., Ogle, S., Lydy, M.J. 2006. Aquatic effects of aerial spraying for mosquito control over an urban area. Environ. Sci. Technol. 40:5817-5822.

Integrated Pest Management Tools and Resources for Protecting Water Quality

Mary Louise Flint
Director, IPM Education and Publications, UC Statewide IPM Program and Extension Entomologist, University of California, Davis, CA 95616
Phone (530) 752-7692, FAX (530) 752-9336, mlflint@ucdavis.edu

Joyce F. Strand, Information Systems Manager, UC Statewide IPM Program, University of California, Davis, CA 95616
Phone (530) 752-8350, FAX (530) 752-6004, jfstrand@ucdavis.edu

Introduction

The University of California Statewide IPM Program has developed a number of web-based resources to help Californians effectively manage pests while protecting water quality. All can be viewed on the UC IPM web site at www.ipm.ucdavis.edu. Products geared at urban audiences include a special section on urban pesticides and water quality directed at consumers and public agencies, a comprehensive database of environmentally sound management practices for hundreds of landscape and home pests plus educational materials for use by UCCE Master Gardeners in their outreach programs. For agricultural audiences, the site features year-round IPM programs for over a dozen crops that outline a comprehensive IPM strategy that can eliminate most water quality risks. These programs are backed up by a WaterTox database that allows users to compare available pesticide options for every pest on 44 crops according to their potential to damage water quality.

Urban Resources

Pesticide users in urban areas are diverse, ranging from licensed pest control professionals to home gardeners, and the UC IPM Program seeks to serve them all; however, the web page currently has a focus on home users and landscape professionals.

The Pesticides and Water Quality section of the web, currently under revision in 2007, provides users with links to relevant public agencies, literature and explanation of issues in lay terms with substantial illustrations. It includes details on how to handle pesticides so they don't get into water as well as alternatives that don't pose water quality risks.

The Pests in Homes, Gardens, Landscapes and Turf section includes information on how to manage over 800 insect, weed, pathogen, nematode and vertebrate pests with tools that pose minimal threat to the environment. Users can access information by plant species for diagnosis or by pest. Included in this database are over 130 Pest Notes, peer reviewed UC ANR publications which are UC's official management guidelines for urban pests. Also online are attractive, short "Quick Tips" with information abstracts in English and Spanish.

Insecticides used on lawns and for the control of ants have been a particular concern for water quality. These two targets accounted for much of the use of organophosphates such as diazinon, which were big urban water quality concerns in the late 1990's (e.g. Domagalski 2000) before their withdrawal from the market and are also prime targets for use of pyrethroid insecticides that have recently been found in urban creeks at toxic levels (Weston et. al. 2006). To address these two important pest management issues, the UC IPM Program has developed online interactive educational modules to provide in-depth information about preventing problems and environmentally sound management approaches with the UC Guide to Healthy Lawns and the Key to Identifying Household Ants.

Agricultural Resources

The UC IPM Program has provided growers and agricultural professionals with web-based pest management information through its Pest Management Guidelines (PMG) database for over 10 years. The program continues to enhance this database and over recent years special attention has been given to helping growers effectively include environmental parameters in their decisions.

The Pest Management Guidelines are UC's official guidelines for pest management in agricultural crops. Written by UC experts, they cover 43 crops or crop groups, floriculture and turfgrass and include suggestions for hundreds of arthropod, pathogen, nematode and weed pests. On the web, PMGs include thousands of photographs to help identify or diagnose problems and natural enemies and provide research-based information on biological, cultural and chemical control alternatives for each pest. Organically acceptable methods are clearly identified. Every insecticide is rated for its impact on natural enemies and information on chemical class and mode of action of every pesticide is included.

The agricultural part of the UC IPM web site has been recently been enhanced by the addition of year-round IPM programs, which outline comprehensive, multi-pest IPM programs that protect the environment while providing effective crop protection. Developed for individual crops, each program guides farmers through a year of monitoring pests, making management decisions and planning for the following season, providing a complete inventory of everything required to carry out a complete IPM program. The programs also outline practices that reduce water quality risks and other environmental problems. Special features include

- Annual IPM checklist for planning and evaluating an IPM program
- Detailed monitoring instructions that include decision thresholds
- Monitoring forms and checklists to print out and use for record keeping
- Printable color photo sheets to identify pest problems and natural enemies
- Pesticide application checklist to identify ways to prevent or mitigate negative impacts
- Links to Pest Management Guidelines for suggestions for nonchemical and less toxic pesticide alternatives and details on biology, monitoring and management for insect, disease, nematode and weed pests.

The year-round IPM programs provide the University of California's "Best Management Practices" (BMPs) for pest management. Growers following these procedures should readily meet requirements of the Clean Water Act. The California USDA Natural Resources Conservation Service (NRCS) has included implementation of a UC IPM year-round program among its suggested practices under the EQIP program with a $125/acre incentive for growers who follow all the steps, maintain checklists and records and avoid use of organophosphate, pyrethroid or emulsifiable concentrate formulations of pesticides when viable alternatives are available. Year-round programs are currently on the web site for alfalfa, almonds, avocado, cotton, grape, nectarine, peach, plum, prune, and tomato. Programs for several other crops are underway.

To help growers and agricultural professionals evaluate the potential water quality risks associated with a pesticide listed in the Pest Management Guidelines, the UC IPM Program has created the WaterTox database. This program uses information from the USDA-NRCS WIN-PST tool to evaluate the potential for pesticides to move with water and eroded soil or organic matter through leaching or adsorbed runoff or solution runoff. Long-term toxicity for fish or humans in water is provided. No ratings for aquatic invertebrates are included because the WIN-PST database does not contain this information.

The WaterTox database is simple to use—users just click on a "Water Quality—Compare Treatments" button at the top of the treatment table in the PMG for each pest. A bar graph appears that includes each pesticide listed as a potential management tool for the pest giving a quick graphic cue for problem pesticides—red bars for problem materials that are likely to move off site, blue bars for safer ones. Growers can also adjust for different application conditions, including application rate and area treated. In most cases, the Pest Management Guidelines provide efficacious alternatives that have low water quality risk. Growers on sites where runoff is a concern can reduce water contamination risks by choosing these.

Literature Cited

Domalgalski, J.L. 2000. Pesticides in Surface Water Measured at Selected Sites in the Sacramento River Basin, California 1996-1998. U.S.Geological Survey Water-Resources Investigations Report 00-4203. Sacramento.

Weston, D.P., R.W. Holmes, I. You, and M.K. Lydy. 2006. Aquatic Toxicity Due to Residential Use of Pyrethroid Insecticides. Environ. Sci. Technol 2005, 39, 9778-9784.
Management Options to Reduce Pyrethroid Insecticides in Tailwater from Row Crops

Management Options to Reduce Pyrethroid Insecticides in Tailwater from Row Crops

Allan Fulton, Farm Advisor, UC Cooperative Extension, Tehama County
1754 Walnut Street, Red Bluff, CA 96080
Phone (530) 527-3101, FAX (530) 527-0917, aefulton@ucdavis.edu

Donald Weston, Department of Integrative Biology, University of California Berkeley
3060 Valley Life Sciences Bldg, Berkeley, CA 94720-3140
Phone (510) 665-3421, dweston@berkeley.edu

Rachael Long, Farm Advisor, UC Cooperative Extension, Yolo County
70 Cottonwood Street, Woodland, CA 95695
Phone (530) 666-8143, FAX (530) 666-8736, rflong@ucdavis.edu

Blaine Hanson, Extension Specialist, University of California Davis
One Shields Avenue, Davis, CA 95616
Phone (530) 752-4639, FAX (530) 752-5262, brhanson@ucdavis.edu

Lau Ackerman, Crops Coordinator, California State University Chico
311 Nicholas C. Schouten Ln, Chico, CA 95928
Phone (530) 521-4617, FAX (530) 898 5952, LAckerman@csuchico.edu

Michael Cahn, Farm Advisor, UC Cooperative Extension, Monterey County
1432 Abbott Street, Salinas, CA 93901
Phone (831) 759-7350, FAX: (831) 758-3018, mdcahn@ucdavis.edu

Erin Osborn, Department of Integrative Biology, University of California Berkeley
3060 Valley Life Sciences Bldg #3140, Berkeley, CA 94720-3140
Phone (510) 665-3421, erinamweg@gmail.com

Michael Mata, LAWR Farm Manager, University of California Davis
One Shields Avenue, Davis, CA 95616
mmmata@ucdavis.edu

Introduction

Pyrethoid insecticides are used to protect a variety of row and orchard crops grown in California, and their use on orchard crops in particular has substantially increased over the past decade (Oros and Werner, 2005). They are used even more extensively in urban areas to control household and landscape insect pests. Pyrethroids are important in agricultural Integrated Pest Management (IPM) because they are economical and effective when biological and cultural methods are not adequate for controlling insect pests and they offer an alternative chemistry to use in rotation with other insecticides. Pyrethroids are relatively less toxic to humans than many other insecticides, with relatively short half-lives lending themselves to safe work environments and safe food supplies.

Increased use of pyrethroid insectides coincided with findings that organophosphates (OP's), another class of insecticides, were contributing to the degradation of surface water quality in both urban and agricultural areas of California. By the late 1990's reliance on OP's declined substantially in agricultural production and pyrethroids often replaced them as a first step to manage this water quality issue (Oros and Werner, 2005). Pyrethroids have a higher affinity to adsorb to fine silt and clay particles and organic material than OP's reducing their mobility in tailwater from irrigated fields and exposure to public waterways (Long, 2005).

By 2003, attention to pyrethroids and their affect on sediment quality in public waterways increased. They were shown to attach to suspended sediments in field runoff, enter receiving waters down gradient, and sometimes accumulating to levels toxic to aquatic species that inhabit sloughs, streambeds, and riverbeds (Weston et al., 2004). Today, numerous conventional pesticide use practices are emphasized to address this environmental concern and to retain the use of pyrethroids as a vital crop protection tool. Some of the primary management practices encouraged include: 1) monitoring of insect pests and beneficial insects to be certain that a crop pest is approaching economic thresholds that warrants control with an insecticide; 2) safe pesticide handling, mixing, and disposal; 3) proper sprayer calibration and use of drift control measures; and 4) preference for ground application methods when sensitive waterways are nearby (O'Connor-Mayer, 2000).

Since pyrethroids adsorb to soils, management practices that minimize the soil loss from irrigated fields are now commonly recommended as complementary measures to more conventional pesticide use practices. Such practices include sediment traps, vegetated drainage ditches, the use of polyacrylamide (PAM), an irrigation water amendment. While often recommended, the research experience with these techniques is relatively limited in California agriculture.

California Experience with Soil Loss and Pyrethroid Reduction Practices

Experiences reported by the Yolo County Resource Conservation District indicated on average 33 to 55 percent capture of sediments in field runoff with sediment traps (YCRCD, 2001). Effectiveness depended on characteristics of the flows and suspended sediments, trap design, and maintenance. A prominent question that remains is how effectively sediment traps can capture suspended fine silt and clay sediments, which are the primary soil particle size fractions that adsorb pyrethoids and that are more susceptible to transport from irrigated fields (Gan et al., 2005).

The first reported California experience with vegetated drainage ditches was initiated in 2004/05 by a collaborative research team of federal EPA and USDA scientists, UC Davis toxicologists, and the Yolo County Resource Conservation District (Denton, 2006). The investigations are underway and findings have not yet been reported widely. Prior to this project, some of the leading research with vegetated drainage ditches was conducted in the Mississippi Delta region. Published results of experience in the Mississippi Delta suggested vegetated drainages may effectively intercept up to 99 percent of pyrethroids in solution and adsorbed to suspended sediments in tailwater from agricultural fields (Cooper, 2004.) These out-of-state experiences with vegetated drainage ditches warrant further research and development within California.

Polyacrylamide (PAM) is a synthetic, high molecular weight, anionic and linear polymer that dissolves in irrigation water and can be used to flocculate soils and control suspended sediments in tailwater from farm fields (Wu, 2001). PAM has been commercially available since 1995 in California. One California study showed that PAM reduced suspended soil particles in furrow irrigation tailwater by as much as 99.7 percent (McCutchan, 1993) and had the potential to be an important tool to manage the quality of agricultural runoff from row crops. With the increasing attention on pyrethroid use in California agriculture and sediment toxicity in down gradient waterways, renewed investigations into PAM appear to have merit. One pertinent research question that merits consideration is whether PAM is environmentally safe for widespread agricultural use. Other questions related to PAM application rates and formulations, efficacy and duration, and use of PAM in combination with sediment traps and vegetated drainage ditches are of interest as well.

Current Experimentation with Soil Loss and Pyrethroid Reduction Practices

In 2006, the State Water Resources Control Board funded a collaborative field investigation of tailwater management practices that reduce soil loss and potential pyrethroid insecticide transport from irrigated fields. The research has been conducted by the University of California and California State University Chico. In 2006, sediment traps, vegetated drainage ditches, and PAM water amendment were evaluated in the experiments. A second year of experimentation will be conducted in 2007. Separately funded experiments with vegetated drainage ditches and PAM are also being conducted by the Department of Pesticide Regulation and the Coalition of Urban Rural Environmental Stewardship (CURES) in the San Joaquin Valley.

UC Experimental Methods and Results

In 2006, field trials were conducted on three research farms located near Davis, Chico, and Salinas, California. Processing tomato, lima bean, and lettuce were grown at each trial, respectively. Clay loam and loam soils were predominant at the Chico and Davis field sites, respectively. Similar experimental designs and methods were used at each location to evaluate sediment traps, vegetated drainage ditches, and PAM for removing suspended sediments and pyrethroids from tailwater runoff. The first season of experimentation at the Salinas trial was only recently completed and is not discussed here except for some preliminary observations regarding sediment traps.

The Chico and Davis experiments involved about 3 acres of a furrow irrigated row crop. The irrigated acreage at each site was split into four plots of about 0.75 irrigated acres per plot. Each plot consisted of about 10 furrows per plot with 60-inch beds between furrows. Gated pipe was used to deliver water at 12 to 16 gallons per minute (gpm) into each furrow and furrow lengths were a minimum of 650 feet long to simulate a commercial scale furrow irrigation system. The plots were cultivated and then sprayed before each irrigation with the pyrethroids lambda-cyhalothrin (Warrior) at Davis or zeta-cypermethrin (Mustang) at Chico using a ground applicator to create a realistic condition that had potential to result in transport of sediments and pyrethroids from irrigated fields. Testing was conducted during four irrigations at the Chico and Davis sites during the summer months of 2006.

Tailwater runoff was directed through a flume with a stilling well and automated datalogger at the bottom of each plot to measure runoff rates and the cumulative volume. Approximately 10-80 gallons of runoff was collected from the tailwater flowing through the flume using a diaphragm pump. The large volume of runoff was collected to insure enough suspended sediment was available to determine pyrethroid concentrations in the suspended sediment. Bed sediments were also analyzed for pyrethroids, and tested for toxicity using the amphipod, *Hyallela azteca*. Total suspended solids (TSS) were determined gravimetrically and the turbidity of the runoff was determined with a nephelometer before the tailwater was directed through either a sediment trap or a vegetated drain ditch. After the tailwater passed through a sediment trap or vegetated drainage ditch the same water quality sampling and determinations were repeated.

Sediment Traps

The sediment traps were dug with a backhoe and lined with plastic at the point where water entered to guard against erosion. At the Chico and Davis trials, the sediment traps were approximately 4 feet wide, 13 feet long, and 4 feet deep and designed to trap sediments in tailwater flows ranging from 60 to 100 gpm. The approximate ratio of irrigated area to the area of the sediment trap was 500:1 at Chico and Davis. Based upon experience from the Chico and Davis trials, the sediment traps at the Salinas trial were enlarged to 7 feet wide, 33 feet long, and 2 feet deep for similar runoff rates to provide a 90 minute settling time for suspended sediments in the runoff. The approximate ratio of irrigated area to the area of the sediment trap was about 50:1 at Salinas.

Replicated field evaluations of sediment traps during two irrigation events at both the Chico and Davis farm sites showed very little, if any, capture and reduction of sediments in tailwater from cultivated row crops grown on clay loam and loam soils. Figure 1 illustrates the concentration of total suspended sediments (TSS) in the runoff before and after it passed through a sediment trap when measured periodically during a two-hour period in one plot at the Davis trial in July. This response was representative of the other replicates at both the Chico and Davis trials. Toxicity tests with the aquatic test organism, *H. azteca* showed 92 to 100 percent mortality when exposed to sediments collected after the tailwater passed through a sediment trap. This also suggested that the sediment traps did not effectively reduce the TSS and pyrethroid insecticide associated with the sediment.

One possible explanation for the lack of sediment and pyrethroid reduction from the traps was that they were undersized in the Chico and Davis trials for the tailwater flows (average 90 gpm) that passed through them. As a result, the sediment traps were enlarged five fold at the Salinas trial but the design change did not improve the capture of sediments. An alternative explanation for this response is that most of the larger suspended sand and large silt particles, 10 to 250 µm diameter, settled out in the field due to constrictions on tailwater flow through the flumes. Settling velocities range from about 0.25 to 4 cm/sec for these larger sediments (Marshall and Holmes, 1979). In contrast, settling velocities for fine silt and clay particles are about 0.001 cm/sec and 0.0001 cm/sec, respectively. As a result, the settling velocities required for the suspended fine silt and clay particles, which tend to adsorb pyrethroids, may simply be too slow for sediment traps alone, to be practical and effective for managing fine suspended sediments and pyrethroids.

Vegetated Drain Ditches

The vegetated drainage ditches were constructed with a shallow "V" ditcher and tractor blade. The vegetated ditches were about 5 feet wide, 1.5 feet deep in the center of the ditch, and 160 feet long with about 0.05 percent grade. The approximate ratio of irrigated area to the area of the vegetated drainage ditch was 33:1 at all three trials. Tall fescue *(Festuca arundinacea)* sod was used to establish vegetation in the ditch. Sod was used at Chico and Davis in 2006 because the trials were not initiated until mid May after most of the rainfall had already occurred and the prime season for establishing the vegetation from seed had passed. Investigations in 2007 will evaluate the ease of establishing a vegetated drainage ditch from seed.

Replicated field evaluations of vegetated drainage ditches during two irrigation events at both Chico and Davis farm sites showed significant improvements in water and sediment quality after tailwater was filtered through the ditch. Figure 2 displays the concentration of TSS in the runoff before and after it was routed through a vegetated drain ditch during a two-hour period in one plot at the Chico trial in July. TSS concentrations were reduced 62 to 73 percent with vegetated drain ditches at the Chico site. This finding was representative of other replicates at the Chico trial and for both irrigation events. The effectiveness of the vegetated drainage ditches was less at Davis but may have been related to challenges with establishing vigorously growing fescue grass in the drainage ditches. Toxicity tests with *H. azteca* showed only 6-8% mortality when exposed to sediment collected at the end of the vegetated drainage ditches at the Chico site. This also suggested that vegetated drainage ditches have potential to effectively reduce TSS concentrations and pyrethroid insecticides associated with the sediments in field runoff.

PAM (polyacrylamide) Water Amendment

PAM was evaluated in one plot at each trial by continuously injecting an emulsified formulation of PAM into the main water supply at a concentration of 5 parts per million (ppm). A separate, gated irrigation pipeline at the head of this plot was used to deliver the amended water. The water quality of the runoff from this plot was compared to the water quality of the runoff from the other three plots where the irrigation water not treated with PAM and before the runoff from these plots was routed through a sediment trap or vegetated ditch. Preliminary testing was also conducted with granular and cake formulations of PAM as an alternative to direct injection into the irrigation water supply.

Field evaluations of PAM treated water at the Chico and Davis trials during four irrigation events at each site demonstrated that a 5 ppm concentration of PAM injected into the water supply was highly effective at reducing TSS in field runoff. Figure 3 shows a 98 percent reduction in TSS in one plot from the Chico trial. Similar results were observed in the other replicates and for the other irrigation events at the Chico and Davis trials.

While the use of PAM resulted in impressive reductions in TSS in the field runoff, sediment toxicity tests revealed no survival of the aquatic test organism, *H. azteca,* when exposed to sediment from the tailditch leaving the PAM plot. The reasons for the toxicity are unclear and experimental steps are being taken to understand it. One possible explanation is that the samples taken to evaluate toxicity were contaminated with pyrethoids since the sampling point was in close proximity to where the insecticide spray applicator turned around along the edge of the field so it may have been affected from field drift. In 2007, water samples and sediments from PAM plots will be collected from the tailwater ditch at a point further away from the edge of field to avoid risk of this type of contamination. Another possible explanation is that

H. azteca is sensitive to PAM-treated tailwater. Laboratory tests are planned to determine if PAM has a direct, adverse effect on the survival of this aquatic organism.

Conclusions

After completion of the first of our planned two years of study, some important finding and questions have become apparent:

- Consistent with California field research dating back to 1993, irrigation water supplies treated with anionic polymers (PAM) are highly effective at flocculating fine suspended sediments in field runoff and preventing them and associated pyrethroid insecticides from being transported from fields. Questions remain unaddressed about the toxicity of PAM in irrigation runoff and survival of the aquatic test organism *H. azteca* exposed to PAM. Preliminary field research in 2006 also suggested that other formulations of PAM besides emulsions may be more convenient and as effective, which may aid adoption of PAM into routine farm management practices.

- Vigorously growing, vegetated drainage ditches show potential to significantly filter and reduce the TSS and associated pyrethroid insecticides from field runoff. High survival rates of the aquatic test organism, *H. azteca,* when subjected to sediments and water samples collected after the tailwater passed through 160 feet of vegetation, were also encouraging. Research in 2007 will seek to confirm the first year of findings and to address other aspects such as ease and cost of constructing vegetated tailwater ditches. More research and development may eventually be needed to adapt this management option from experimental to commercial scales.

- Sediment traps, by themselves, were not effective at capturing fine silts and clay suspended sediments and associated pyrethroid insecticides from field runoff. The settling velocities for these very fine suspended solids that pyrethroids attach to appear to be too slow for this management option to be practical. However, it is possible that sediment traps used in combination with PAM may be a viable management option deserving further research and development.

Literature Cited

Cooper, C., M. Moore, E. Bennett, S. Smith, J. Farris, C. Milam, and F. Shields. 2004. Innovative Uses of Vegetated Drainage Ditches for Reducing Agricultural Runoff. Water and Science Technology. 49:117-123.

Denton, D., J. Wrysinski, M. Moore, C. Cooper, J. Miller, V. DeVlaming, M. Barbour, W. M. Williams, J. Rodgers, and P. Robbins. 2006. Benefits of Vegetated Agricultural Drainage Ditches (VADD) as a Best Management Practice in Yolo County, California. Soil and Water Conservation Society. http://www.ars.usda.gov/research/publications/.

Gan, J., Lee, S.J., Liu, W.P., Haver, D.L. and Kabashima, J.N. 2005. Distribution and persistence of pyrethroids in runoff sediments. Journal of Environmental Quality 34:836-841.

Long, R., J. Gan, and M. Nett. 2005. Pesticide Choice: Best Management Practice (BMP) for Protecting Surface Water Quality in Agriculture. University of California, Division of Agriculture and Natural Resources. Publication 8161.

Marshall, T.J. and J.W. Holmes. 1979. Soil Physics. Cambridge University Press. pp.345.

McCutcheon, H., P. Osterli, and J. Letey. 1993. Polymers Check Furrow Erosion, Help River Life. California Agriculture, 47:10-11.

O'Connor-Mayer, P.J. 2000. The Safe and Effective Use of Pesticides. Second Edition. University of California Statewide Integrated Pest Management Project. Agriculture and Natural Resources Publication 3324.

Oros, Daniel R. and Werner, Inge. 2005. Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley. White Paper for the Interagency Ecological Program. SFEI Contribution 415. San Francisco Estuary Institute, Oakland, CA.

Weston, D.P., You, J. and Lydy, M.J. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environmental Science and Technology 38:2752-2759.

Wu, Loasheng. 2001. Polyacrylamide (PAM) – Effective Erosion Fighter and Infiltration Enhancer but Not a Conserver of Water. Quarterly Publication of the Department of Environmental Sciences. University of California, Riverside.

Yolo County Resource Conservation District (YCRCD). 2001. CALFED Water Use Efficiency Program: Yolo County Resource Conservation District Pilot Program 2001. http://www.yolorcd.ca.gov.

Figures

Figure 1. Comparison of total suspended sediments (TSS) in irrigation runoff before and after the tailwater is routed through a sediment trap at the Davis field site.

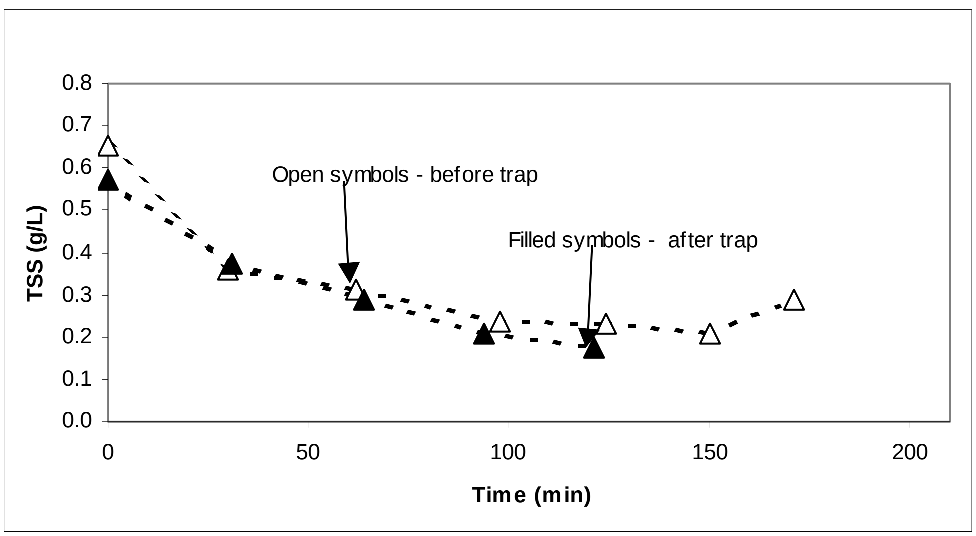


Figure 2. Comparison of total suspended sediments (TSS) in irrigation runoff before and after tailwater is routed through a vegetated drainage ditch at the Chico field site.

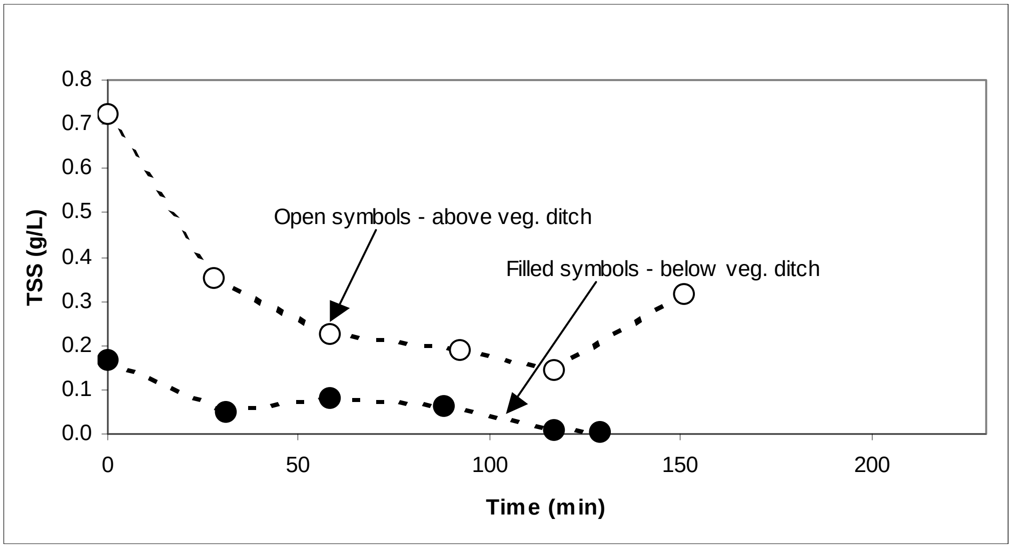
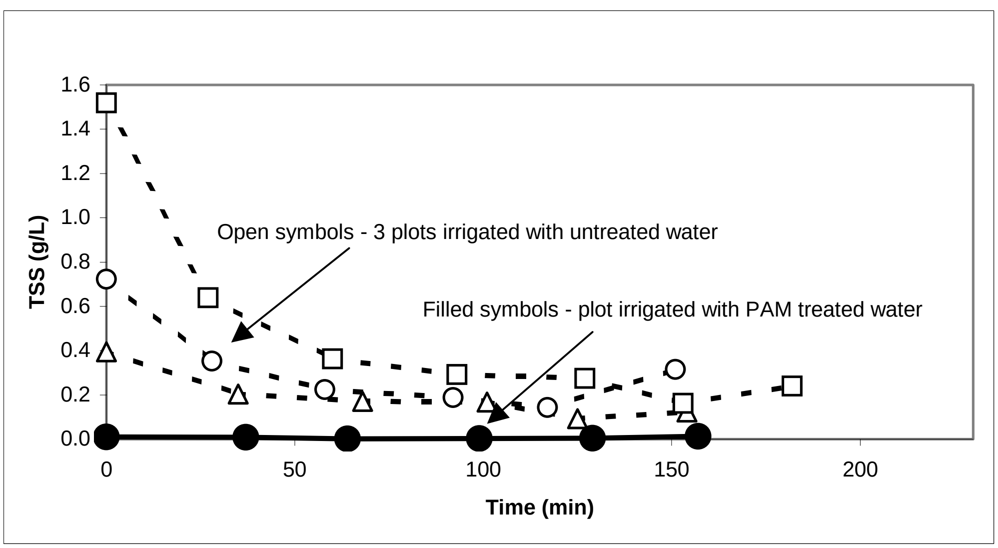


Figure 3. Comparison of total suspended sediments (TSS) in irrigation runoff at the Chico field site from three plots irrigated with untreated water and one plot irrigated with PAM treated water.



Session II

Nutritional Development of Tree, Vine, Tomato & Organic Rice Crops

Session Chairs:

Rob Mikkelsen, Potash & Phosphate Institute

Ben Nydam, Dellavalle Laboratory Inc.

Is There A Biological Rationale For Foliar Fertilizers In Almond Production?

Patrick Brown,
Department of Plant Sciences, University of California, One Shields Avenue, Davis, CA 95616
Phone (530) 752 0929, phbrown@ucdavis.edu

Introduction

Foliar fertilization has been used by fruit growers since the early 19th century (Gris, 1884) and has become an important management practice in all well managed orchard systems. Though they are invariably more expensive than soil based fertilizers, foliar fertilizers nevertheless are widely and increasingly used in tree crop production. Two rationales are cited as justification for their use, 1) to overcome soil chemical or physical conditions that prevent nutrient uptake and 2) to provide targeted nutrients to prevent short term or 'transient' deficiencies such as those that may occur during reproductive growth, or periods of peak demand. Whereas the use of foliar fertilizers to overcome soil physical and chemical properties is well defined and many examples of its implementation are available, the fundamental nutritional physiology to support the use of foliar fertilizers to overcome 'transient' deficiencies is scant and generally inadequate to predict or explain the usefulness of these practices.

The focus of this paper will be a discussion of transient nutrient deficiencies as a justification for the use of foliar fertilizers. Considerable research into the physicochemical considerations for the use of foliars and the use of foliars to address soil chemical or physical conditions that prevent nutrient uptake is available from other reviews (Weinbaum, 1989; Schonherr, 2006) and numerous field experiments and will not be considered here.

It is widely hypothesized that transient nutritional deficiencies occur as a result of limitations in uptake or restrictions in nutrient delivery during periods of peak nutrient demand. To address this issue many horticultural producers utilize foliar fertilizers since this allows for highly localized and specifically tailored nutrient applications that are not as easily provided using solid or blended products. This approach is particularly relevant for micronutrients. Very little research is available, however, that demonstrates the effectiveness of foliar fertilizers and the role they play in ensuring continued nutrient supply during times of peak demand. In general the supply of fertilizers to roots through soil applications is far cheaper and in many (but not all) cases results in a more economical use of the applied nutrient (Weinbaum, 1989). Identification of the situations where foliar fertilization offers a specific advantage is critical to economic success and provides useful information on the relationship of demand to fertilization strategy.

Over the past 10 years we have conducted considerable research into the effectiveness of targeted B fertilization and have observed that foliar B applications frequently increase fruit set and yield if applied during reproductive growth. These responses are seen even in the absence of symptoms of B deficiency. Biochemical, isotopic and molecular experimentation demonstrate that a transient B deficiency is common during reproductive growth and that foliar B is frequently effective even when soil B is available. Additionally, research and field observations of localized spur and branch K deficiency in trees well supplied with soil K, provide evidence that within tree deficiencies can occur even in the presence of adequate soil nutrient.

In the following, experimental evidence for the occurrence of transient nutrient deficiencies and their efficient correction by foliar fertilization is presented. The broader implications of these results as a rationale for foliar fertilizers is discussed.

Materials and Methods

Response of Pistachio to foliar B.

In 1990-94 a large experimental site with potential B deficiency was established in mature Pistachio (*Pistacia vera* L.) cv. 'Kerman' trees growing in Yolo County, California, USA. In total over 1000 trees (tree spacing 5 x 6 m with 333 trees ha^{-1}) were utilized in this experiment. Treatments consisted of either 0, 12, 23, 35, and 47 g B per tree as Solubor ($Na_2B_8O_{13}\cdot 4H_2O$, containing 20.5% B) applied to the soil in November, or as foliar application of Solubor at four levels (0, 490, 1225, and 2450 mg•L^{-1} B) at a rate of 1000 L of water per hectare (equivalent of 0, 1.53, 3.82, and 7.64 g B per tree) by a tractor - mounted sprayer in January (late dormant spray) and again in July. A total of four fields were used (two foliar, two soils). In each field, the experiment was designed as a randomized complete block with 10 trees per replicate and five replicates per block. All treatments were bordered on all sides by two rows of untreated trees. In addition, a subset of trees (10 replicate trees per timing arranged in a completely randomized design) was utilized for the spray timing trial. In this site trees were sprayed with 490 ppm B at either of five dates, from late dormant through full leaf emergence. Total yield was determined on each tree and related to B application.

Response of Olive to foliar Boron. (from Perica et al, 2001)

In 1998 an orchard of bearing olive (*Olea europaea* L.) cv. 'Manzanilla' with July tissue B concentration of 17 ppm was selected in Butte County, California, USA. Experiments were conducted in both 1998 and 1999. The trees were planted at a density of 370 trees per hectare (Oroville). Boron as Solubor ($Na_2B_8O_{13}\cdot 4H_2O$), containing 20.5% B, was applied at four levels (0, 246, 491, and 737 mg.L^{-1} B), at a rate of 935 L of water per hectare by a tractor - mounted sprayer. Boron was applied 3 weeks before anthesis on April 21, 1998 and May 1, 1999. The treatments were imposed in a randomized block of five adjacent trees within a treatment, replicated six times, making a total of 120 experimental trees per site. Single border trees separated the treatments and minimized the effect of cross-treatment contamination. The design was identical in both experiments.

On each replicate tree, five shoots in 1998 and twenty shoots in 1999, uniform in length and exposure with full floral differentiation (>95%), were selected before anthesis and tagged a few nodes above the shoot base. In 1998 all flowers and fruit set on each tagged shoot were counted, in 1999 the total number of inflorescences was determined on each tagged shoot. At anthesis (May 10, 1998 and May 18-22, 1999) five uniform shoots per tree were detached and taken to the lab where the number of complete and incomplete inflorescences per shoot was counted and the number of perfect and imperfect flowers was recorded. ‘Complete inflorescence’ in this report is defined as an inflorescence with at least one single complete flower; ‘incomplete inflorescence’ means no single flower in an inflorescence is completely developed. The number of perfect vs. imperfect flowers was also counted on a single inflorescence arbitrarily chosen from the fourth node from the base of the detached shoot.

Transgenic manipulation of B transport in Tobacco (from Brown et al., 1999).

Three tobacco (*Nicotiana tabacum* L.) lines were used; SR1, wild-type tobacco; A4, tobacco transformed with the anti-sense gene construct for S6PDH; and S11, tobacco line transformed with the sorbitol synthesizing sense construct (Tao et al., 1995). A4 and SR1 served as controls. A4 and S11 are identical in all regards with the exception of the orientation of the S6PDH coding region with respect to the CaMV 35S promoter.

Homozygous seed of each tobacco line were germinated, then grown in vermiculite for four weeks with adequate supply of all nutrients including 0.05 ppm B. At four weeks, plants were transferred to hydroponic solutions with aeration (1/2 strength Hoagland solution (Hoagland and Arnon, 1950), minus B) and the following treatments imposed. 1), 0.05 ppm B, consisted of a continual supply of 0.05 ppm B in the rooting medium; 2), 0 ppm B, received no B in the rooting medium; 3) ‘foliar’ treated plants, received bi-weekly foliar applications of B to three mature leaves (described below) with no B supplied in the root nutrient medium.

Potassium Deficiency in Almond. (from Reidel et al, 2004)

Potassium fertilizer was applied to drip irrigated 'Nonpareil' almond trees in a Modesto, California orchard at the rates of 0, 240, 600, and 960 lbs K_2O/A/year as K_2SO_4, beginning in 1998. The fertilizer was applied directly beneath six drip emitters per tree, split 3 times (May 23, June 17, and July 3) in 1998 and 2 times (Feb. 26 and April 29) in 1999. Forty individual branch units from trees in the control (0 K) and 960 lbs K_2O/A rates (“low-K” and “high-K”, respectively) were selected to monitor yield determinants and individual spur longevity over several years. Yield and leaf K concentrations were also measured.

Results:

Response of Pistachio to Foliar and Soil B:

Table 1 compares the effectiveness of soil B applications with respect to foliar B applications. It can be seen that soil applied B was most effective at raising tissue B levels. Plants supplied 170 to 227 g•tree^{-1} Solubor (35 to 47 g•tree^{-1} B) in 1990 had tissue B concentrations (in 1992) higher than trees that received foliar applications alone. Nevertheless, trees that received foliar B showed a positive yield response while those receiving soil B did not. This indicates that adequate leaf B status does not ensure optimal tree productivity. Apparently, foliar applications of B serve a unique role in enhancing pistachio fruit set.

Table 2 demonstrates that the most effective time for application of foliar B was the late dormant spray (immediately pre-anthesis) in which a yield increase of as much as 20% over unsprayed control trees were recorded. Later sprays effectively increased tissue B levels but did not increase fruit yield, though all B sprayed trees yielded more than trees not receiving supplementation. The effectiveness of early but not late B sprays, is evidence that B is critical for pollination or fertilization of pistachio flowers.

Response of Olive to Foliar :

Foliar B application immediately pre-anthesis significantly altered the ratio of perfect to imperfect flowers, increased fruit set (results not shown) and increased final yield (Table 3). Soil B status did not influence the response of plants to foliar B (results not shown).

Transgenic manipulation of phloem B transport and its effect on susceptibility to B deficiency in tobacco:

Following removal of B from the growth medium, significant flower abortion and subsequently reduced seed production occurred in both wild-type and antisense tobacco plants (in which B is immobile), demonstrating that a brief deficiency of B can have a profound effect on flowering (Fig. 1). The application of foliar B had no beneficial effect on these plants. Tobacco plants with the capacity to transport B in the phloem to the flowers (transgenic) did not exhibit rapid flower abortion and in all cases produced significantly more seed than plants with limited phloem B mobility (Fig 1). With the application of foliar B, the transgenic tobacco performed equally to the control plants receiving root B indicating that the capacity to effectively use foliar fertilizers can entirely replace the need for soil B supply. The reduced seed set in the transgenic tobacco grown for an extended period in 0 ppm B is a consequence of the depletion of all remobilizable B and the ultimate occurrence of B deficiency throughout the plant.

Potassium Deficiency in Almond:

The application of differential K rates in 1998 and 1999 increased average leaf K in 1998, 1999 and 2000 but had no significant effect on tree yield in 1998 or 1999 and a small (18%) increase in yield in 2000 (control<240=600=960 Kg/ha). The majority of the effect of K on yield was a consequence of prior year fruiting status, and K application rate expressed at an individual spur level. Table 4 illustrates that addition of K increased the number of $vegetative_{1999}$ spurs that became reproductive in 2000 by 14%, and the number of $reproductive_{1999}$ spurs that remained reproductive in 2000 by 20%. Spurs represent only a small percentage of whole plant biomass and were the only site at which clear K deficient leaves were observed (Fig 2a). The highly localized occurrence of K deficiency on otherwise symptom free trees is also frequently seen in leaves immediately adjacent to fruit in almond and pistachio even in trees well provided with soil K (Fig. 2a,b).

Discussion:

The results of experimentation in both Pistachio and in Olive as well as many other reports in the literature (Nyomora et al., 1997; 1999 and references therein) demonstrates that foliar B application can result in correction of an apparent deficiency that is not responsive to soil B application nor easily indicated by leaf B concentrations. This is most apparent in pistachio where foliar B fertilization applied pre-anthesis increases pollen germination, reduces blanking and non-splits (results not shown) and consequently increases yield. This stimulation occurs even in trees with summer leaf B concentrations in excess of 150 ppm, indicating that there is a specific requirement for B in the developing flower. Foliar applications are the most effective method to ensure adequate B for the flowers. Soil applications of B are effective at raising leaf B levels but are not as effective as foliar sprays at increasing yield since B availability from soil is apparently not coincident with reproductive demand.

The apparent superiority of foliar B can best be explained as a consequence of a transient inadequacy in B supply to the reproductive tissues from the soil. This may occur as a consequence of low root activity in cool soils, high B requirement in developing flowers, or low transport of B to the reproductive tissues. All of these explanations suggest that transient deficiencies of B can occur and they may not be efficiently corrected by soil fertilization. To our knowledge this is the clearest example of a transient nutrient deficiency and a justification for application of foliar fertilizers.

The suggestion that the phloem immobility of B greatly enhances susceptibility to transient limitations in supply of B from the soil was verified using a novel transgenic approach. In tobacco plants in which phloem B mobility was enhanced through introduction of the gene for sorbitol synthesis, the susceptibility of these cultivars to B withdrawal from the soil solution was greatly reduced. These transgenic tobaccos were also capable of obtaining their B requirements solely through foliar fertilization. Phloem immobility clearly contributes to plant susceptibility to transient nutrient deficiencies.

In Almond, and other nut crops, nutrient demand is highly localized both within the tree and within the year coinciding with periods and sites of rapid fruit development. Local and temporal deficiencies can therefore occur at an individual branch or spur level even for an element of high within plant mobility such as K. Since whole tree aggregate above ground nutrient demand drives root nutrient uptake (Gessler et al 2004), it may be predicted that highly localized deficiencies in individual spurs may not per se, trigger enhanced root uptake. The relationship between nutrient demand and uptake is further complicated since high levels of CHO demand to meet the demand of the rapid crop growth also inhibits soil nutrient uptake. Thus there is a propensity for a uniquely high incidence of local nutrient deficiencies in high yield years that may not be efficiently corrected by supplemental soil applications. Under these circumstances it is generally believed by growers that foliar applications are uniquely effective. Though this presumption has a logical basis in science, and is supported by anectodal field evidence, there have been no studies demonstrating that foliar fertilization can effectively or uniquely enhance yield under these circumstances.

Summary:

The results provided here, clearly demonstrate that transient B deficiencies occur and can be important determinants of yield. The evidence also suggests that foliar B fertilizers can on occasions, be uniquely effective at correcting these deficiencies. Based upon these results, we conclude that transient deficiencies of B may occur as a consequence of a combination of spatial and temporal variations in plant nutrient demand and supply, and will be influenced by the relative mobility of the nutrient in the plant. Though these results demonstrate the occurrence of transient nutrient deficiencies of B and provide a biological justification for the use of foliar B, they do not predict plant response to other foliar fertilizers. Nevertheless, we have provided evidence of a strong temporal and spatial demand for K in Almond and a high demand for macronutrients also likely exists in many nut crops and has been shown to have a significant negative effect on return yield.

While these results support a role for targeted foliar fertilizers we are unaware of any studies that specifically address the role of foliar fertilizers to correct these spatially variable or temporally transient deficiencies. Further research must be conducted to determine if transient deficiencies are relevant to the management of nutrients in perennial crops and if targeted foliar fertilizers can play a unique role in their correction.

References.

Brown P.H. and Hu H. 1996 Phloem mobility of boron is species dependent. Evidence for phloem mobility in sorbitol rich species. Ann Bot **77**: 497-505

Brown P.H., Bellaloui N., Hu, H., and Dandekar A. 1999 Transgenically enhanced sorbitol synthesis facilitates phloem boron transport and increases tolerance of tobacco to B deficiency. Plant Physiology 113:17-20

Greve C, and Labavitch J.M. 1993. Cell wall metabolism in ripening fruit. V. Analysis of cell wall synthesis in ripening tomato pericarp tissue using a d-[U-13C]glucose tracer and gas chromatography-mass spectrometry. Plant Physiol **97**: 1456-1461

Gris E. 1884. Nouvelles experiences sur l'action des composes ferrugineux solubles, appliqués à la vegetation et specialement au traitement de la chlorose et àla denilite des plantes. Comp. Rendes. (Paris) 19:118

Hoagland D.R., and Arnon D.I. 1950. The water-culture method for growing plants without soil. California Experiment Station Circular 347. The College of Agriculture, University of California, Berkeley, CA

Nyomora A.M.S., Brown P.H., and Freeman M. 1997. Fall foliar-applied boron increases tissue boron concentration and nut set of almond. J. Amer. Soc. Hort. Sci. 122:405-410.

Nyomora A.M.S., Brown P.H., and Krueger B. 1999. Rate and time of boron application increase almond productivity and tissue boron concentration. HortScience 34:242-245

Perica, Slavko, Patrick H. Brown, Joseph H. Connell, Agnes M.S. Nyomora, Christos Dordas, Hening H, and James Stangoulis. 2001. Foliar boron application improves flower fertility and fruit set of olive. HortScience 36(4):714-716.

Reidel, Edwin.J., Patrick H. Brown, Roger Duncan, Richard Heerema, and Steven Weinbaum. 2004. Sensitivity of yield determinants to potassium deficiency in 'Nonparei' almond (prunus dulcis (Mill) D.A.Webb). Journal of Horticultural Science and Biotechnology. 79:906-910

Schonherr, J. 2006. Characterization of aqueous pores in plant cuticles and permeation of ionic solutes. J. Exp. Bot 57:2471-2491

Sibbett, G.S., Ferguson L., Anderson D., Freeman M.W., and Welch. G. 1986. Timing Manzanillo olive harvest for maximum profit. California Agr. 40:19-22.

Tao R., Uratsu S.L., and Dandekar A.M. 1995. Sorbitol synthesis in transgenic tobacco with apple cDNA encoding NADP-dependent sorbitol-6-phosphate dehydrogenase. Plant Cell Physiol 36: 525-532

Weinbaum S.A. 1989. Foliar nutrition of fruit trees, pp81-100. In Nuemann, P.M. (ed). Plant growth and leaf applied chemicals. CRC Press. Boca Raton.

Youssefi, Farbod, Steven A. Weinbaum, and Patrick H. Brown. 2000. Regulation of nitrogen partitioning in field-grown almond trees: effects of fruit load and foliar nitrogen applications. Plant and Soil 227:273-281.

Table 1. Influence of B application on yield, bud and July leaf B of pistachio

FOLIAR ($mg{\bullet}L^{-1}$ B)	YIELD (kg in-shell splits/tree)	$mg{\bullet}kg^{-1}$ B Buds	Leaves (July)
0	8.6	35	170
490	10.0*^{z}	37	185
1225	11.8**	39	171
2450	9.5	41	210
SOIL ($g{\bullet}tree^{-1}$ B)			
12	8.6	35	172
23	8.6	38	189
35	9.1	44	201
47	9.5	50	219

[z]*, ** significantly greater than control at 0.05, and 0.01%, respectively.

Table 2. Effect of application date of foliar B (1225 mg•L^{-1} B) on yield and leaf B in Pistachio

APPLICATION DATE	GROWTH STAGE	YIELD[1] (kg)	LEAF B (JULY) mg•kg^{-1}
28-Feb	Late Dormant	32**	188
19-Mar	Early Bud Break	24	188
3-Apr	Flowering	25	187
17-Apr	Leafing Out	23	256**
8-May	Fully Leafed Out	22	468**

** significantly greater than control at 0.01%
[1]All yields are fresh weight of fruit per tree.

Table 3. Influence of pre-anthesis foliar B on olive reproduction[z].

	1998	1999	
B spray rate (mg.L^{-1})	Imperfect flowers	Imperfect flowers	Yield (kg/tree)
0	55 a[y]	49 a	12.6 b
246	35 b	38 b	14.9 a
491	33 b	40 b	17.8 a
737	48 a	47 a	13.5 b

[z]Applications were only effective pre-anthesis
[y]Within a column values followed by different letters differ significantly at $p < 0.05$ by Fisher's LSD.

Table 4. Effect of K treatment and spur bearing status in 1999 on status of spurs in 2000.

Spur bearing Status In 1999	K-availability	Spur bearing status in 2000: Vegetative N	(%)	Flowering n	(%)	Total
vegetative	high-K	18	(14)	114	(86)	132
vegetative	Low-K	29	(25)	89	(75)	118
fruiting	high-K	60	(52)	55	(48)	115
fruiting	low-K	53	(60)	36	(40)	89
Totals		160		294		454

Figure. 1. Seed yield of tobacco lines (transgenic, wild type, antisense) grown for 28 days with adequate B then transferred to either 0 ppm B, 0.05 ppm B supplied to the roots, or 100 ppm B supplied to three mature leaves. Seed yield was determined 56 days after transfer to treatment solutions. Values represent mean +/- standard error of six replicates.

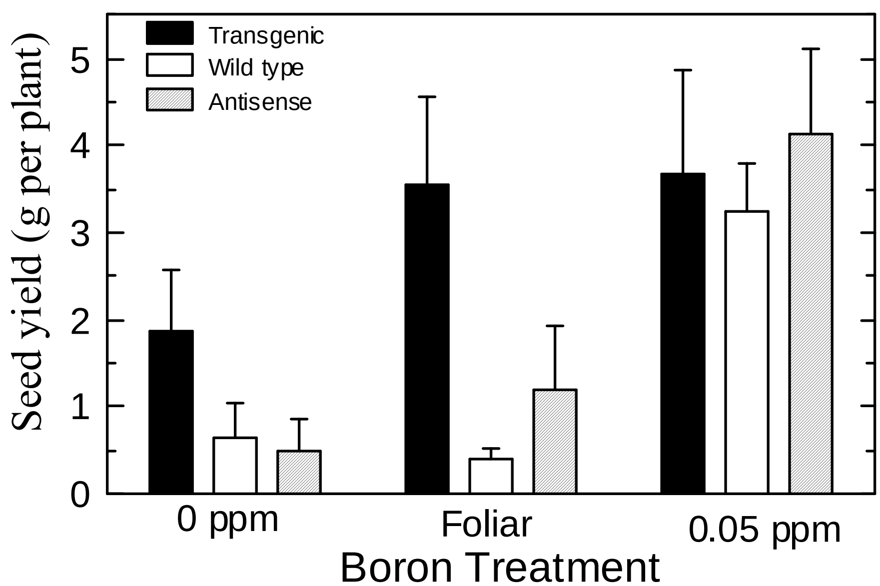


Figure 2a and 2b: Potassium deficiency in leaves immediately adjacent to almond (2a) and Pistachio (2b) fruits. Leaves on these trees not directly associated with fruit were not deficient according to current UC standards.

Improving the Nutrient Efficiency of Tree Crops

Franz Niederholzer
UCCE Farm Advisor, Sutter/Yuba Counties
142A Garden Hwy, Yuba City CA 95991
Phone (530) 822-7515, Fax (530) 673-5368, fjniederholzer@ucdavis.edu

Introduction

Essential mineral nutrients applied to crops are a cost to growers and, poorly managed, contaminate air and/or water resources. Over the past 30+ years, fertilizer costs (USDA, 2006) and evidence of the negative impact of fertilizer nutrient contamination of air and water resources have increased significantly (Tilman et al., 2002). Therefore, an increase in nutrient efficiency, measured as net income, plant yield, or nutrient absorbed or applied per unit available nutrient, should benefit the grower and the environment*. Of particular interest to California agriculture is tree crop nutrient efficiency, as perennial crops continue to replace annual crops in many regions of the central valley – a region of the state with rapid population growth and subsequent pressures on air and water resources. The purpose of this paper is a brief review of factors affecting tree crop nutrient efficiency with a focus on nitrogen (N), potassium (K), and zinc (Zn) – the nutrients most commonly limiting tree crop production in California. A review of past advances in tree crop nutrient efficiency and current challenges in tree crop and orchard nutrient efficiency will be presented.

Much of the information presented in this paper was developed from research to improve N use efficiency (unit N absorbed by crop per unit available N) in tree crops. Nitrogen is frequently the most limiting essential nutrient in natural ecosystems (Tilman et al., 2002), and, in agriculture, combines the factors of high crop need and environmental risk associated with its use as a fertilizer (Tilman et al., 2002; Weinbaum et al., 1992)}.

Nutrient efficiency has different definitions, including economic and agronomic yield per unit applied or available N. Wide differences in production economics between tree crop species affect nutrient efficiency presented using economic factors. To avoid confusion, tree crop efficiency is defined in this paper as nutrient use efficiency, which is calculated as unit nutrient absorbed by the plant per unit nutrient available.

Tree Nutrient Efficiency

Research conducted in the last quarter century of the 20th century has led to a significant increase in knowledge useful for improving tree nutrient efficiency. These works document the influence of application timing, application method, soil type, rootstock, irrigation management, tree growth/crop load and other factors on tree nutrient efficiency. The affect of these different factors on nutrient efficiency varies between

---

*The benefit to the grower and the environment may not be equal – at least in the short run (Raum and Johnson, 1999). However, since excessive nutrient application and tree uptake may reduce fruit quality or yield and/or increase production costs (Crisosto et al., 1997; Daane et al., 1995), economic and environmental goals may be closer than is immediately evident.
Elements, and are particularly influenced by chemical form and soil mobility.

The use of destructive sampling of mature trees, an expensive and time consuming practice, has been key to many of these developments, as differences in tissue analyses do not necessarily reflect changes in whole tree nutrient content. Research into N efficiency also benefits from the availability of ^{15}N, the non-radioactive isotope of N.

In general, attempts to efficiently fertilizer tree crops has followed the process outlined tree nutrient budgets (Anderson et al., 2006; Brown et al., 2004; Tagliavini et al., 1996): 1) determine nutrient requirements through the season for adequate plant growth and high crop yield, 2) Evaluate stored or natural N availability, 3) determine if additional N is needed in excess of stored or natural N, 4) assess application efficiency, and 5) determine final amount of fertilizer to deliver (if any).

All these considerations assume biological and physical soil environment (adequate moisture, well drained soils, neutral soil pH, etc.) suitable for good tree health and crop production. Water management in tree crops affects growth and mobile nutrient movement (Quiñones et al., 2005).

Nitrogen

A nutrition program that delivers the most efficient N use in tree crops currently includes soil application of biologically realistic N fertilizer rates synchronized with periods of elevated tree N use applied and managed to reduce losses of N from the root zone. Foliar application of N fertilizer may be included in this program. Such a program may include some measure of soil N (non-fertilizer N) or early-season tree N status and was developed, at least in part, using research results discussed below.

Mineral nitrogen, as nitrate or ammonium, can be highly mobile in soil if managed improperly, which contributes to lower N efficiency. Fertilizer applied as ammonium or urea can volatilize as ammonia from the soil surface (Mattos et al., 2003). Nitrate-N, the form of N most commonly found in neutral pH, well-drained soils, can be absorbed by tree roots, immobilized in soil organic matter, absorbed by weeds, leached below the root zone with excess soil water, or lost as NO_x following denitrification (Havlin et al., 1999). Consequently, N fertilizer use efficiency (fertilizer N absorbed by the tree per unit fertilizer N applied) estimates range from <10-50% for soil applied N fertilizer in tree crop production with efficiencies in the middle to lower end of this range commonly reported (Huett and Stewart, 1999; Weinbaum et al., 1984).

However, despite these multiple competitive fates in orchard soils, fertilizer N can be rapidly absorbed by tree roots. Fertilizer N appears in the canopy of mature trees within 4 weeks of application to the soil (Huett and Stewart, 1999). Relatively rapid N uptake permits the use of multiple, small doses of fertilizer N to improve N efficiency (Quiñones et al., 2003).

Most efficient N applications are synchronized with tree N demand. There is a high correlation between healthy tree N absorption potential and tree N demand and tree N demand is highest during periods of rapid vegetative and/or fruit growth (Muñoz et al., 1993; Weinbaum et al., 1978). Differences in tree age, tree size, and crop load potential affect the relative amount of

N needed for the appropriate horticultural benefit (e.g. rapid tree growth or high quality crop production) depending on tree age.

The importance of relative crop load to N efficiency in mature tree crops can not be overestimated. Crop load is the most significant factor affecting mature, bearing tree N requirement and a key input to prescribing efficient fertilizer N applications. [Tree N crop content is second only to K in many crops, for an example, see (Weinbaum et al., 1994).] In addition, due to recycling of nutrients from fallen leaves and prunings, the crop represents the primary loss of nutrient from the orchard over time (Weinbaum et al., 1992)

Current soil N absorption is not needed to sustain tree growth at all times during the season. Consequently, fertilizing during periods of low N use and reduced potential for N use efficiency should be avoided. Trees store N in leaves and/or woody tissue (Niederholzer et al., 2001; Rosecrance et al., 1998b). Stored N can buffer growth from the need for current root N uptake and allows the temporal separation of tree growth and N absorption. However, storage sites are limited to woody tissue in deciduous trees during the winter, and N demand to fill this storage capacity is relatively small compared to that during periods of rapid growth in the summer (Niederholzer et al., 2001). Thus, fall N fall N fertilizer demand is significantly less than during the spring and summer in many tree crops.

Tree genotype, not human management practices; determine changes in tree N content. Trees appear to have a finite capacity to use available soil N and demonstrate the capacity to self-regulate net N uptake once that capacity has been met (Youssefi et al., 2000). Thus, since excess N cannot be forced into trees, matching accurate amounts of fertilizer N to periods of rapid growth and crop N requirements is a major step towards improving tree N efficiency. N application, without reducing application rate to reflect current tree N demand (growth and/or storage) in the early spring or fall risks highly inefficient losses of fertilizer N from the root zone via leaching water or denitrification.

Application methods and practices can also affect tree N efficiency. Foliar N application, particularly using urea (Furuya and Umemiya, 2001), can improve tree N efficiency. Foliar urea application provides significantly higher N efficiency than soil applied N (Rosecrance et al., 1998a), but repeated applications are needed to deliver total annual N requirement (Johnson et al., 2001). Peach trees fertilized with fertilizer N via foliar spray, only, produced smaller fruit than soil-fertilized trees (Johnson et al., 2001), but fruit size was not affected when apples were similarly treated (Dong et al., 2005). Nitrate leaching was reduced when apple trees were treated with repeated urea foliar applications compared with the same rates and timings of soil applied urea (Dong et al., 2005). Injection of soluble N fertilizers with irrigation water (fertigation) can facilitate more efficient use of fertilizer N (Quiñones et al., 2003), but excessive water application can push mobile N forms (nitrate and/or urea) below at least a portion of the active root zone (Hanson et al., 2006).

Areas of further research to improve tree nutrient efficiency as defined in this paper include use of slow release N fertilizer, evaluation of the potential for ammonia losses from trees and soil, plant breeding to select for genotypes that produce more crop per lower unit N, and the affect of root zone nitrate concentration in/on N uptake potential. An effective tool to estimate soil N available through mineralization from soil organic matter in a given year would be valuable to better predict the quantity of soil available N. An effective test to assess tree N status in spring time would also be helpful. Finally, research to develop low cost practices to increase soil organic matter could help to increase soil N availability, improve soil water holding capacity and reduce nitrate leaching.

General guidelines to improve fertilizer N efficiency in California tree Crops

- Match rates and application timing to tree demand (fruit growth, shoot growth, and storage). See N budget models (Anderson et al., 2006; Brown et al., 2004)
- Don't apply N when leaves are not present.
- On highly permeable soil (loamy sand, sands) multiple, small applications of fertilizer N should be used to reduce the potential of N leaching.
- Incorporate as quickly as possible, by water or cultivation, broadcast urea or ammonium fertilizers.
- Irrigate efficiently, using some form(s) of use-based scheduling (ET, soil moisture, plant moisture, etc.)
- Time fertilizer injection so that fertilizer is delivered just into the active root zone.
- Use leaf analysis and a visual examination of tree growth to help evaluate fertilizer program/rates and guide future practices.
- Consider foliar urea application instead of late summer/post harvest soil N application.

Potassium

While tree K needs are as much or more than for N in many crops, K use efficiency in tree crops presents different challenges and is much less studied. [K is generally believed to be less of a potential environmental contaminant than N.]

In soil, the K^+ is generally much less mobile that nitrate-N, especially in high-K affinity soils (e.g. soils high in organic matter and//or clay). Consequently, K losses from the root zone are significantly less than for N, but it is often necessary to apply K fertilizer in advance of crop need for effective and efficient K tree use. Use of fertigation compared with localized soil application (banding) of K fertilizer can accelerate plant availability of fertilizer K (Uriu et al., 1980). Calcium application (as gypsum) can be used to move K further into the soil and perhaps increase K availability (Carlson et al., 1974). Foliar application(s) of potassium nitrate deliver K more efficiently than soil applications (Southwick et al., 1996).

Zinc

Tree Zn requirement is very small relative those for N or K (Weinbaum et al., 1994). Zinc is highly immobile in most orchard soils, and annual or semi-annual foliar applications are commonly used to improve tree Zn status. Because of the risk of phytotoxicity form highly soluble foliar Zn materials sprayed in the growing season, inefficient rates of Zn are applied as insoluble Zinc oxide or in the fall or dormant periods as zinc sulfate. Research in California is currently underway to evaluate a range of different Zn foliar materials in an effort to improve tree Zn efficiency (Johnson and Brown).

Rootstocks for the same crop may display different Zn absorption potential (Brown et al., 1994). Thus, a long term strategy for improving Zn efficiency may be found in development of rootstock(s) with high Zn absorption capacity.

Orchard Nutrient Efficiency

Variability in tree size and yield across a field is common in California orchards. Yet, in the author's experience, fertilizer is applied in most of those orchards at a fixed rate across the entire field, regardless of tree health or size. Even when that fixed rate is developed with attention to all the factors listed in the section above for maintaining efficient tree nutrient use, variability in tree size, crop load, soil depth, soil texture and other factors will affect overall orchard nutrient efficiency.

Development and recent commercial availability of remote sensing technology now allows identification of distinct management zones within an orchard (Zaman and Schumann, 2006a), even down to a per tree basis (Zaman and Schumann, 2005a; Zaman et al., 2005b). Commercial availability and accuracy of variable rate fertilizer application technology to utilize this information differs between foliar or soil applied fertilizers.

Tree sensors, commercially available on existing sprayers, allow efficient fertilizer delivery to foliar and no application to gaps in the tree row. While inherent differences in canopy spray coverage result from radically delivered spray patterns common to most orchards sprayers (Manktelow et al., 2004), the combination of tree sensors with foliar fertilizers allows for the most efficient nutrient delivery systems currently available to growers

Soil applied variable rate fertilizer delivery (VRFD) is currently under study for use in orchards. Considerable research has been reported from Florida, where shallow water tables and readily leachable sandy soils present a significant challenge to efficient nutrient management in citrus production. In those orchards systems, tree canopy has been correlated with crop yield (Zaman et al., 2006b), and tree size mapping and variable rate fertilizer application on a per tree basis in large scale experiments in commercial orchards has reduced N and K application 38% without reducing tree nutrient status across the grove (Zaman et al., 2005b). Improvements in equipment response time to allow accurate tree to tree changes in fertilizer delivery are needed (Schumann et al., 2006). [Current VRFD equipment was developed for large soil management units in annual crop production developed from remote sensing of soil differences, and accurate rate delivery changes are made in 4 seconds – roughly the time it takes for the application equipment to pass from one tree to the next in a commercial citrus grove.] While research in pistachio orchards in California has documented individual tree yield differences across large orchards (P. Brown, personal communication), limited public research has, to the author's knowledge, been conducted into orchard-scale nutrient efficiency in California orchards.

Conclusions

Improvements in tree crop nutrient efficiency should improve grower's bottom line while reducing potential for environmental degradation due to nutrient movement out of the orchard. Use of established models for matching fertilization need and the rate of fertilizer to be used, should be extensively ground tested. More research is needed to apply those models to management zones within orchards to improve overall orchard nutrient efficiency.

References

Anderson, K.K., J. Grant, S.A. Weinbaum, and S. Pettygrove. 2006. Guide to efficient nitrogen fertilizer use in walnut orchards. University of California Agricultural and Natural Resources Division, Oakland, CA. Publication 21623.

Brown, P.H., Q. Zhang, and L. Ferguson. 1994. Influence of rootstock on nutrient acquisition by pistachio. J. Plant. Nutr. 17:1137-1148.

Brown, P.H., Q. Zhang, M. Stevenson, and R. Rosecrance. 2004. Nitrogen Fertilization Recommendation for Almond. University of Californa.

Carlson, R.M., J.R. Buchanan, T.E. Kapustka, and K. Uriu. 1974. Displacement of fertilizer potassium in soil columns with gypsum. J. Am. Soc. Hort. Sci. 99:221-222.

Crisosto, C.H., R.S. Johnson, T.M. DeJong, and K.R. Day. 1997. Orchard factors affecting postharvest stone fruit quality. HortSci 32:820-823.

Daane, K.M., R.S. Johnson, H.T. Ramirez, T.J. Michailides, G.Y. Yokota, C.H. Crisosto, and D.P. Morgan. 1995. Excess nitrogen raises nectarine susceptibility to disease and insects. Calif. Ag. 49:13-18.

Dong, S., D. Neilsen, G.H. Neilsen, and L.H. Fuchigami. 2005. Foliar N application reduces soil NO3--N leaching loss in apple orchards. Plant Soil 268:357-366.

Furuya, S., and Y. Umemiya. 2001. The influence of chemical forms on foliar-applied nitrogen absorption for peach trees. Acta-Hort. 594:97-103.

Hanson, B., N. O'Connell, J. Hopmans, J. Simunek, and R. Beede. 2006. Fertigation with microirrigation., University of California Agricultural and Natural Resources Communication Services, Oakland, CA. Publication 21620.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 1999. Soil Fertility and Fertilizers. 6th edition ed. Prentice Hall, Upper Saddle River, New Jersey, 07458.

Huett, D.O., and G.R. Stewart. 1999. Timing of ^{15}N fertilizer application, partitioning to reproductive and vegetative tissue, and nutrient removal by field-grown low-chill peaches in the subtropics. Aust J. Agric. Res. 50:211-215.

Johnson, R.S., R.C. Rosecrance, S.A. Weinbaum, H. Andris, and J. Wang. 2001. Can we approach complete dependence on foliar-applied urea nitrogen in an early-maturing peach? J. Amer. Soc. Hort. Sci. 126:364-370.

Manktelow, D.W., S.J. Gurnsey, and A.M. MacGregor. 2004. Deposit variability and prediction in fruit crops: what use are label rates anyway? Asp. Appl. Biol. 71 269-278.

Mattos, D., Jr., A.K. Alva, S. Paramasivam, and D.A. Graetz. 2003. Nitrogen volatilization and mineralization in a sandy entisol of Florida under citrus. Commun. Soil Sci. Plant Anal. 34:1803-1824.

Muñoz, N., J. Guerri, F. Legaz, and E. Primo-Millo. 1993. Seasonal uptake of ^{15}N-nitrate and distribution of absorbed nitrogen in peach trees. Plant and Soil 150:263-269.

Niederholzer, F.J.A., T.M. DeJong, J.L. Saenz, T.T. Muraoka, and S.A. Weinbaum. 2001. Effectiveness of fall versus spring soil fertilization of field-grown peach trees. J. Amer. Soc. Hort. Sci. 126:644-648.

Quiñones, A., J. Bañuls, E. Primo-Millo, and F. Legaz. 2003. Effects of ^{15}N application frequency on nitrogen uptake efficiency in *Citrus* trees. J. Plant. Physio. 160:1429-1434.

Quiñones, A., J. Bañuls, E. Primo-Millo, and F. Legaz. 2005. Recovery of the ^{15}N-labelled fertilizer in citrus trees in relation with timing of application and irrigation system. Plant Soil 268:367-376.

Raum, W., R., and G. Johnson, V. 1999. Improving nitrogen use efficiency for cereal production. Agron. J. 91:357-363.

Rosecrance, R.C., R.S. Johnson, and S.A. Weinbaum. 1998a. The effect of timing of post-harvest foliar urea sprays on nitrogen absorption and partitioning in peach and nectarine trees. J. Hort. Sci. Biotech. 73:856-861.

Rosecrance, R.C., S.A. Weinbaum, and P.H. Brown. 1998b. Alternate bearing affects nitrogen, phosphorus, potassium and starch storage pools in mature pistachio trees. Ann. Bot. 82:463-470.

Schumann, A.W., W.M. Miller, Q.U. Zaman, K.H. Hostler, S. Buchanon, and S. Cugati. 2006. Variable rate granular fertilization of citrus groves: spreader performance with single-tree prescription zones. Appl Eng Agric 22:19-24.

Southwick, S.M., W. Olson, J. Yeager, and K.G. Weis. 1996. Optimum timing of potassium nitrate spray applications to 'French' prune trees. J. Amer. Soc. Hort. Sci. 121:326-333.

Tagliavini, M., D. Scudellazi, B. Marangoni, and M. Toselli. 1996. Nitrogen fertilization management in orchards to reconcile productivity and environmental aspects. Fert. Res. 43:93-102.

Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature 418:671-677.

Uriu, K., R.M. Carlson, D.W. Henderson, H. Schulbach, and T.M. Aldrich. 1980. Potassium fertilization of prune trees under drip irrigation. J. Amer. Soc. Hort. Sci. 105:508-510.

USDA, E.R.S. 2006. U.S. Fertilizer Use and Price. USDA ERS.

Weinbaum, S.A., M.L. Merwin, and T.T. Muroaka. 1978. Seasonal variation in nitrate uptake efficiency and distribution of absorbed nitrogen in non-bearing prune trees. J. Amer. Soc. Hort. Sci. 103:516-519.

Weinbaum, S.A., R.S. Johnson, and T.M. DeJong. 1992. Causes and consequences of overfertilization in orchards. HortTech. 2:112-121.

Weinbaum, S.A., I. Klein, F.E. Broadbent, W.C. Micke, and T.T. Muraoka. 1984. Effects of time of nitrogen application and soil texture on the availability of isotopically labeled fertilizer nitrogen to reproductive and vegetative tissue of mature almond trees. J. Amer. Soc. Hort. Sci. 109:339-343.

Weinbaum, S.A., F.J.A. Niederholzer, S. Ponchner, R.C. Rosecrance, R.M. Carlson, A.C. Whittlesey, and T.T. Muraoka. 1994. Nutrient uptake by cropping and defruited field-grown 'French' prune trees. J. Amer. Soc. Hort. Sci. 119:925-930.

Youssefi, F., S.A. Weinbaum, and P.H. Brown. 2000. Regulation of nitrogen partitioning in field-grown almond trees: effects of fruit load and foliar nitrogen applications. Plant Soil 227:273-281.

Zaman, Q.U., and A.W. Schumann. 2005a. Performance of an untrasonic tree volume measurement system in commercial citrus groves. Precision Agric. 6:467-480.

Zaman, Q.U., and A.W. Schumann. 2006a. Nutrient management zones for citrus based on variation in soil properties and tree performance. Precision Agric. 7:45-63.

Zaman, Q.U., A.W. Schumann, and W.M. Miller. 2005b. Variable rate nitrogen application in Florida citrus based on ultrasonically-sensed tree size. Appl Eng Agric 21:331-335.

Zaman, Q.U., A.W. Schumann, and K.H. Hostler. 2006b. Estimation of citrus fruit yield using ultrasonically-sensed tree size. Appl Eng Agric 22:39-44.

Fertility Management of Processing Tomato

Tim Hartz
Extension Specialist, Department of Plant Sciences
University of California, One Shields Ave, Davis, CA 95616
Phone (530) 752-1738, FAX (530) 752-9659, tkhartz@ucdavis.edu

Introduction

Processing tomato production has changed greatly over the last decade. Improvement in varieties continues to increase yields and fruit quality. Transplanting has become the norm for most growers. The rapid adoption of drip irrigation is transforming not only how water it applied, but how crop fertility is managed. In light of these changes it is worthwhile to reconsider fertilizer management practices, particularly for drip-irrigated culture.

Nutrient uptake patterns

Processing tomato crops exhibit a characteristic nutrient uptake pattern – slow through field establishment and early vegetative growth, accelerating during fruit set and fruit bulking, and slowing as the crop matures. Fig. 1 shows a typical nutrient uptake pattern for a 40 ton/acre crop.

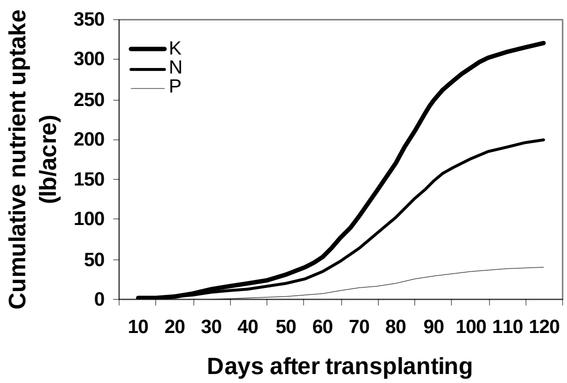


Fig. 1. Pattern of N / P/ K uptake in processing tomato.

At harvest the total macronutrient content of the whole crop (vines and fruit) averages approximately 200, 40, and 320 lb N, P, and K, respectively. A ton of fruit typically contains 3-4 lb N, 0.3-0.5 lb P, and 4-6 lb K.

Nitrogen management

Dozens of field trials in California have shown that conventionally-irrigated processing tomatoes generally require no more than 100-150 lb of fertilizer N/acre to achieve maximum yield; the remaining N comes from residual soil NO_3-N and soil organic N that is mineralized (made available) during the season. Since tomato is a moderately deep-rooted crop, NO_3-N leaching loss during the season is seldom large. In a study of 10 processing tomato fields, Krusekopf et al (2002) found that the residual soil NO_3-N prior to sidedressing averaged approximately 100 lb/acre in the top 2 feet, but varied among fields from 30-200 lb/acre. A fruit yield response to sidedress fertilization was observed in only 4 of the 10 fields. They concluded that soil sampling after crop establishment could help guide N fertility decisions, with fields with residual soil NO_3-N >15 PPM in the top foot requiring minimal N sidedressing to reach maximum yield potential.

If a grower has been efficiently managing water and N fertility with furrow irrigation, switching to drip irrigation is unlikely to reduce N fertilizer requirement significantly; growers who are able to dramatically cut back on N fertilizer application after switching to drip were probably over-fertilizing and/or over-irrigating their conventionally-irrigated fields. N fertilizer requirement may actually increase with drip, since higher yields are possible, and the mineralization of soil organic N may be limited because the surface soil stays dry. A reasonable N fertigation plan would be to apply a seasonal total of 100-180 lb N/acre, in multiple applications concentrated just before and during the rapid uptake phase of the crop. Light-textured soils, fields coming out of lightly fertilized crops (like wheat), fields with very heavy fruit set, and fields that have received significant winter rains (which may have leached residual soil NO_3-N) will in general require more N fertigation than fields of heavier soil texture that are coming out of a more heavily fertilized crop, or that receive little winter rain.

Phosphorus management

Few field trials on P fertilization of processing tomatoes have been conducted in recent years, so we have an incomplete picture of P fertilizer requirement for transplant, high-yield hybrid tomatoes. Based on research conducted in the 1970s and 1980s, the soil test threshold for crop yield response is between about 12-20 PPM P using the Olsen (bicarbonate) extraction procedure. Some early season vegetative growth response has been documented with P application in fields with higher soil test P, but that response has not generally carried through to produce a fruit yield response. It is probable that a 20 PPM soil test threshold for P fertilizer response is still an appropriate guideline for high-yield, transplanted tomatoes. Beyond soil test P level, the other main factor governing soil P availability is soil temperature; the lower the temperature, the less available the P. Using an anion membrane extraction technique, Johnstone et al. (2005) determined that, in California mineral soils, bioavailable P increased approximately 20% with each 10^{o}F increase in soil temperature. This means that, at the same soil test P level, P availability of a field planted in May would be > 20% higher than a field planted in March.

Although P fertilizers can be applied through drip irrigation (with proper safeguards to prevent chemical precipitation), fertigation may not be the best way to apply P. P supply is most limiting early in the season, when the soil is colder, and the limited root system of the crop reaches only a small volume of soil. This argues for applying most or all of the season's P requirement preplant, or at planting, regardless of irrigation technique. Placement of P close to the young plants maximizes availability. When P is applied through buried drip lines, the extent of movement away from the point of injection is governed by soil texture and pH; in alkaline soil of medium to heavy texture, fertigated P may move only a few inches from the tape, making it less available than if banded close to the plant row or applied in a transplant drench. Once the crop has developed a large, vigorous root system soil P is more readily accessible to the crop, and in-season P applications are not often necessary.

Potassium management

Potassium management is a complicated issue. K affects not only fruit yield, but also fruit color; the fruit disorder 'yellow shoulder' (YS), in which a ring of tissue surrounding the stem scar remains yellow after the fruit has ripened, is directly related to K nutrition. Soil K availability is also more complex than N or P, and therefore a more expansive discussion is warranted. The typical commercial lab evaluates soil K availability by extracting the soil with an ammonium acetate solution and measuring the cations removed from the soil exchange sites. The results are typically given either in parts per million (PPM) or in milliequivalents (meq)/100 g of soil (1 meq K/100 g = 390 PPM K). However, to get the most complete picture of relative K availability you also need to consider the relative abundance of K in relation to the other cations. The cation exchange of California soils is typically dominated by calcium, magnesium, potassium and sodium, collectively called the 'base exchange'. The higher the percentage of base exchange represented by K (on a milliequivalent basis), the more readily available K is for plant uptake; this is because there is competition among the various cations for uptake by plant roots. This is particularly true in the case of Mg, which tends to suppress K uptake. The higher the percentage of base exchange that is K, the more readily available K will be to the crop. Plants obtain K directly from soil solution and from cation exchange sites. Additionally, K trapped within silt and clay particles is in equilibrium with exchange site and soil solution K; as plants remove K, some of this trapped (or 'fixed') K is slowly brought into soil solution, available for plant uptake. When K fertilizer is applied to soil, the process works in the opposite direction; as the soil solution and the exchange sites are enriched by the fertilizer K, some of that K will become trapped in these 'fixation' sites. Much of this K movement into fixation sites occurs during soil drying cycles. Measured rates of fixation of applied K vary from $< 10\%$ to $>$ 80% in Central Valley soils; K fixation rate is insignificant in very sandy soil and in soil with very high exchangeable K level, but it can be very high in heavy-textured soil with moderate to low exchangeable K.

Unlike nitrate, which is highly mobile, K moves very little in soil. The effective movement in water flow from the point of fertilizer application is typically no more than a few inches; the effective movement by diffusion is even less. This means that extensive rooting is required for the plant to successfully mine K from the entire soil profile, and that applied K must be placed close to a zone of intensive rooting to be maximally effective.

In light of the preceding discussion, and based on a series of 16 potassium fertilization trials conducted over the past decade (Hartz et al., 2000, 2005), the following recommendations can be made regarding K fertilization of processing tomatoes:

1) for conventionally-irrigated fields there is a high probability of increased yield with K fertilization in soil with exchangeable K < 130 PPM; yield improvement is increasingly less likely as soil exchangeable K increases above that level. Soils with low exchangeable K and low K intensity ($< 2\%$ of base exchange) are particularly likely to require fertilization. K fertilization may reduce, but will typically not eliminate, YS. Achieving significant reduction of YS may require more fertilization than is required for maximum yield; between 100-200 lb K_2O / acre should be sufficient to maximize yield in most circumstances, but even twice that amount may not reduce YS to acceptable levels. The effectiveness of preplant and sidedress K applications can be limited by soil fixation of applied K, and by the distance of the application from the zone of maximum root density. Management practices that encourage extensive rooting will increase crop K uptake. Conversely, practices that limit root development (causing soil compaction by working wet fields, for example) will aggravate K deficiency.

2) drip-irrigated fields may have a higher K requirement than if those same fields were furrow-irrigated. Yield expectations will be higher, and the extra fruit will require more K uptake. Secondly, because buried drip tends to reduce rooting in the top 6 inches of soil (the soil zone with the highest exchangeable K level), and to restrict rooting only to the area wetted by the drip

tape, the potential for K uptake from the soil is reduced. The good news is that applying K through the drip tape delivers K directly to the most concentrated root zone; also, because the soil around the tape is maintained moist, K fixation is limited. We have achieved significant tomato yield increases and fruit color improvements with K fertigation in fields with exchangeable K > 200 PPM. K fertigation has been most effective in increasing yield if it is applied from just before full bloom (when the early fruits are about 1 $^{1/2}$ inch in diameter, but before any gel development) until about 10% red fruit. Seasonal fertigation rates of 100-200 lb K_2O/acre should be sufficient in most cases. The form of K applied (sulfate or chloride) has not affected relative crop performance.

Micronutrients

Micronutrients are seldom limiting in Central Valley soils. Historically, soil Zn deficiency was relatively widespread, but addition of Zn in preplant fertilizers has enriched soil Zn supply to the point that Zn deficiency is now rare. While it is theoretically possible to encounter other micronutrient deficiencies, it is unlikely. The relative supply of Ca and Mg has implications for soil structure and water infiltration characteristics, but a nutrient deficiency of either element is unlikely. Blossom end rot of tomato fruit, often thought of as a Ca deficiency, is nearly always the result of transient water stress rather than lack of soil Ca; Ca moves within the plant in the transpirational stream, and even a temporary interruption of that stream prevents sufficient Ca from reaching rapidly growing tissues like young fruits.

Tissue testing

Plant tissue testing can help identify growth-limiting nutrient deficiency. Whole leaf total N/P/K analysis evaluates overall nutrient status, while petiole analysis provides a measure of unassimilated nutrients (NO_3-N, PO_4-P, and K) taken up but not yet incorporated into plant structures. Tissue analysis is most useful from early flowering through full bloom. Nutrient deficiency is rare before flowering (with the possible exception of P); after full bloom tissue nutrient concentration, particularly for K, is heavily influenced by fruit load; low tissue values may not reflect nutrient deficiency as much as nutrient export to the fruit.

A nutrient monitoring survey of >100 commercial fields was conducted in 1993-94 (Hartz et. al., 1998), and standards for whole leaf nutrient sufficiency were determined. (Table 1). These standards were determined by mathematically comparing the leaf nutrient concentrations of high-yield fields with those of low yield fields, and calculating an optimum range that encompassed the majority of nutritionally balanced, high-yield fields. These sufficiency levels are similar to prior UC guidelines for N and P, but considerably lower for K.

Table 1. Whole leaf macronutrient sufficiency guidelines.

	Sufficiency range by growth stage	
Nutrient	First flower	Full bloom
% N	4.6 - 5.2	3.5 - 4.5
% P	0.32 - 0.49	0.25 - 0.41
% K	2.2 - 3.5	1.6 - 3.1

Petiole analysis is also popular. Unfortunately, recent research on several vegetable crops, including processing tomatoes, has shown that petiole analysis is not a dependable measurement on which to base fertility management decisions. Factors such as temperature, solar radiation level, soil moisture availability, and even varietal differences can confound the relationship between soil nutrient availability and crop nutrient uptake, and affect the rate at which the plant incorporates the inorganic ions into organic compounds. *Very low* petiole nutrient concentrations are generally indicative of soil nutrient deficiency, but above 'obviously deficient' levels, these confounding factors render petiole nutrient concentration virtually meaningless. The historical petiole 'sufficiency' values developed by UC and other sources in the 1970s and 1980s were generally derived from only a few replicated fertilizer trials. Since only a narrow range of field environments were represented in these studies, the resulting values are not broadly applicable to the industry, and are generally higher than actually necessary for optimum growth. I do not recommend routine petiole analysis as a primary fertility management tool. Whole leaf total nutrient concentration, and soil testing, give more reliable information.

Given the preceding discussion it is clear that nutrient analysis of petiole sap is also a questionable technique. Beyond the limitation of petiole analysis per se, sap analysis adds additional variability because nutrient concentration varies with petiole water content. Furthermore, Cardy meters are less reliable than well-maintained laboratory equipment, and their use adds another layer of inaccuracy. Cardy meter analysis of petiole sap is a very rough diagnostic, and should only be used to distinguish obvious deficiency from probably sufficiency.

References

Hartz, T.K., E.M. Miyao and J.G. Valencia. 1998. DRIS evaluation of the nutritional status of processing tomato. HortScience 33:830-832.

Hartz, T.K., E.M. Miyao, R.J. Mullen and M.D. Cahn. 2000. Potassium fertilization effects on processing tomato yield and fruit quality. Acta Horticulturae 542:127-133.

Hartz, T.K., P.R. Johnstone, D.M. Francis and E. M. Miyao. 2005. Processing tomato yield and fruit quality improved with potassium fertigation. HortScience 40:1862-1867.

Johnstone, P.R., T.K. Hartz, M.D. Cahn and M.R. Johnstone. 2005. Lettuce response to phosphorus fertilization in high phosphorus soils. HortScience 40:1499-1503.

Krusekopf, H.H., J.P. Mitchell, T.K. Hartz, D.M. May, E.M. Miyao and M.D. Cahn. 2002. Pre-sidedress soil nitrate testing identifies processing tomato fields not requiring sidedress N fertilizer. HortScience 37:520-524.

Rootstock Influence on Grapevine Nutrition: Minimizing Nutrient Losses to the Environment

James A. Wolpert and Michael M. Anderson
Department of Viticulture and Enology
University of California, Davis, CA 95616
Phone (530)754-6245, jawolpert@ucdavis.edu

Introduction

In vineyards, the two most widely applied macro-nutrients are nitrogen (N) and potassium (K). Rootstocks are known to differ in their ability to take up N and K but whether and to what extent rootstocks can influence fertilizer programs is not known.

Rootstock use began first in France for resistance to the soil pest phylloxera (*Daktulosphaira vitifolia* Fitch) (Pongracz 1983). However, *V. riparia, V. rupestris* and their hybrids failed to tolerate the high limestone soils of France. Avoidance of lime-induced chlorosis in hybrids with *V. berlandieri* was the first demonstration that rootstocks had an effect on vine nutrition. With the failure of ungrafted vineyards in California (Wildman 1986) and the later failure of AXR#1 rootstock to type B phylloxera (De Benedictis and Granett 1993), phylloxera-resistant rootstocks have been used throughout California coastal regions. Emphasis on canopy management (Smart 1985) and the more recent interest in developing appropriate "vine balance" (Kliewer and Dokoozlian 2000) has led to a desire among researchers and viticulturists to understand rootstock effects on vine growth. One aspect of that effect is to understand the influence of rootstocks on vine nutrition.

That rootstocks can influence foliar nutrient levels is a well accepted concept (May 1994). However, specific interactions of rootstock, scion, soil type and cultural practice are not well understood. A thorough analysis of the literature will not be attempted here but examples of rootstock effects on nutrition include: N utilization by scions (Keller *et al* 2001), improved uptake of K (Brancadoro *et al* 1994, Wolpert et al 2005) and exclusion of salts in the soil solution (Walker *et al* 2002). In California, N and K are the major elements of interest (Christensen *et al* 1978) and were the focus of this study.

Materials and Methods

Three rootstock experiments are reported (Table 1). Two vineyard sites were located in the Sacramento River Delta, near the town of Hood, CA. The scions were Cabernet Sauvignon and on a Tinnin loamy sand and Chardonnay on an Egbert clay (sandy loam variant) (Anamosa, 1998). A third site was located in Amador County's Shenandoah Valley, with Zinfandel as the scion, on a Sierra sandy loam soil. These three vineyards evaluated an identical set of 14 rootstocks (Table 2). Rootstock was the only treatment. None of the sites was deficient in nitrogen or potassium.

Petiole and blade tissues were collected from rootstock treatments at each of three phenological stages: bloom, veraison and harvest, and were collected over three years, 1995 to 1997. Bloom samples were leaves opposite clusters, while veraison and harvest samples were the most recently fully expanded leaves. At each sampling date, 20 petioles and blades were collected per treatment-replicate. Petioles were oven-dried and sent to an analytical laboratory at the University of California, Davis, for processing and analysis. All samples were analyzed for two forms of nitrogen: nitrate-nitrogen (NO_3-N), expressed as parts per million (ppm) and total nitrogen (total N), expressed as %N, and for potassium (K) expressed as %K. Only NO_3-N data are presented.

Results

Nitrate-N, however, was extremely variable among years, rootstocks, sites and, most particularly, from replicate to replicate within a rootstock, site and year.

For Chardonnay, petiole nitrate values (Table 3) were lower at bloom (386 ppm) and veraison (382 ppm) but higher at harvest (947 ppm). In general, the highest bloom petiole nitrate values were seen in 1103P, followed by a group above 500 ppm including Ramsey, 110R, Freedom and St. George. Rootstocks with lowest bloom petiole nitrate values, with levels below 200 ppm, included 1616, 44-53 and Harmony.

For Cabernet Sauvignon, average NO_3-N levels in petioles (Table 4) showed wide variability among replicates of rootstocks, so much so that with a plot average of only 567 ppm, a difference of 400 ppm was not statistically significant. In general, petiole NO_3-N declined from bloom to veraison and increased at harvest to levels similar to those at bloom. However, this was not true for all rootstocks nor was it true for all years (year data not shown). Rootstocks with high NO_3-N values at bloom were Ramsey and St. George while those with low values were 420A, 1616C and 44-53. Petiole NO_3-N levels significantly declined between bloom (567 ppm) and veraison (307ppm) but by harvest had returned to a level (525 ppm) similar to that at bloom.

For Zinfandel, petiole NO_3-N levels (Table 5) showed an extreme decline for all rootstocks from bloom (1317 ppm) to veraison (80 ppm) and harvest (102 ppm). Large differences in bloom NO3-N values among rootstocks were seen with the highest being O39-16 and 5BB while the lowest was 420A (514). However, due to high variability differences as large as 500 ppm were not significantly different. Interestingly, although 420A had the lowest NO_3-N levels at bloom it was highest at both veraison (149 ppm vs a plot average of 80 ppm) and harvest (230 ppm versus a plot average of 102).

Discussion

Rootstocks had an impact on petiole levels of nitrate N at three sampling dates throughout the growing season. However, rootstocks differed in their ranking among the trials and differed in their seasonal pattern of change.

However, a determination of why rootstocks perform differently is confounded in this case by several factors. Firstly, these three rootstock trials are located in different sites with different scions, soils and climates. Management practices from site to site are the not the same. Even in cases in which wine quality goals are similar the production practices used to achieve that goal may be quite different. Also, the growth and yield components of grapevines on rootstocks are considerably different; resulting in different crop levels and leaf areas, and no analysis of these effects on tissue nutrient status has yet been accounted for. A more complete analysis will be done in a due course.

Another component hampering interpretation with historical literature is the fact that as many as 20 rootstocks are used in commercial production or in experiments but usually only four to six are used in an experiment. Therefore, a thorough understanding of rootstock performance is not possible if a common set for comparison is not present.

Finally, there has been a tacit assumption that there is no rootstock: scion interaction, that scions respond in a relatively similar manner on rootstocks as they do ungrafted (Christensen 1984). However, recent demonstration that scion genotype affects rootstock response with respect to water relations (Virgona *et al* 2003), suggests that a closer examination of rootstock effect on nutrition may be warranted.

In current standard practice, nutrition of grapevines is monitored primarily by analysis of nutrients at bloomtime in petiole tissue and comparing them against established values for critical levels (Cook and Kishaba 1956, Christensen *et al* 1978). A fundamental tenet is that data are reproducible and that amounts of variability in data are acceptable. An examination of petiole nitrate-nitrogen data reveals that they are quite variable. For example, no significant difference was found in bloom petiole nitrate-nitrogen in Cabernet Sauvignon (Table 5), despite a range in levels from 258 to 799 ppm. Large differences can also be seen in seasonal changes, for example, in Zinfandel petiole nitrate nitrogen, varying from 1317 ppm at bloom to 80 ppm at harvest.

Based on observations of variability, an examination was made of Coefficients of Variance (CV) for each measured nutrient in three trials at each sampling date (Table 6). CV values show that data from blades are more reproducible than data from petioles and that samples taken at bloom are more reproducible than samples taken at harvest. It also shows that total N is the most reproducible measurement followed by K, latter values almost all falling well below the acceptable target of 15 for biological systems. However, the values for nitrate are acceptable only in blades. Values in petioles, except for one, range from 29 to 40, meaning that the data are not reliable enough to be useful measure of vine N status.

With respect to environmental considerations, it is clear that rootstocks can influence petiole nutrient values. It is possible that, with additional data, rootstocks could be selected to overcome site limitations in some mineral elements. It is also quite possible that current guidelines for N analysis and response are not accounting for variability in petiole nitrate values and are giving growers a mistaken view of their N status. The result would be unneeded N application, wasteful at the very least and harmful to the plant and the environment at worst. Given that bloom petiole N is the recommended standard measure, we suggest that new consideration be given to testing and using some other measure of vine N.

Acknowledgements: Authors thank Trinchero Family Estates and Montevina Vineyards. Cooperation of UC Viticulture Advisors Donna Hirschfelt (Amador) and Chuck Ingles (Sacramento) is greatly appreciated. Funding provided by American Vineyard Foundation and USDA Viticulture Consortium.

Literature Cited

Anamosa, P. R. 1998. Characterization of Soil Beneath the Field Evaluation of Wine grape Rootstocks Research Trials. Master's Thesis, University of California, Davis, 32p.

Brancadoro, L., L. Valenti, A. Reina and A. Scienza. 1994. Potassium content of grapevine during the vegetative period: the role of the rootstock . J. Plant Nutrition 17:2165-2175.

Christensen, P. 1984. Nutrient level comparisons of leaf petioles and blades in twenty-six grape cultivars over three years (1979 through 1981). Amer. J. Enol. Vitic. 35:124-133.

Christensen, L.P., A. N. Kasimatis and F. L. Jensen. 1978. Grapevine nutrition and fertilization in the San Joaquin Valley. University of California, Division of Agriculture and Natural Resources, Publication 4087, Oakland, CA, 40 p.

Cook, J. A. and T. Kishaba. 1956. Petiole nitrate as a criterion of nitrogen needs in California vineyards. Proc. Amer Soc. Hort. Sci. 68:131-140.

Cook, J. A. and L. A. Lider. 1964. Mineral composition of bloomtime grape petiole in relation to rootstock and scion variety behavior. Proc. Amer. Soc. Hort. Sci. 84:243-254.
De Benedictis, J. A. and J. Granett. 1993. Laboratory evaluation of grape roots as hosts of California grape phylloxera biotypes. Amer. J. Enol. Vitic. 44:285-291.
Kliewer, W. M and N. K. Dokoozlian. 2000. Leaf area/crop weight ratios of grapevines: Influence of fruit composition and wine quality. *In:* Proceedings of the ASEV 50th Anniversary Annual Meeting (June 19 – 23, 2000, Seattle, WA) American Society for Enology and Viticulture, Davis, CA.
Keller, M., M. Kummer, and M. Carmo Vasconcelos. 2001. Reproductive growth of grapevines in response to nitrogen supply and rootstock. Austr. J. Grape Wine Res. 7:12-18.
May, P. 1994. Using Grapevine Rootstocks: The Australian Perspective. Winetitles, Adelaide, 62p.
Pongracz, D.P. 1983. Rootstocks for grape-vines. David Philip Pub., Cape Town, 150p.
Smart, R. E. 1985. Principles of grapevine canopy microclimate manipulation with implications for yield and quality: A review. Amer. J. Enol. Vitic. 36:230-239.
Virgona, J.M., J. P. Smith and B. P. Holzapfel. 2003. Scions influence apparent transpiration efficiency of *Vitis vinifera* (cv. Shiraz) rather than rootstocks. Austr. J. Grape Wine Res. 9:183-185.
Walker, R. R., D. H. Blackmore, P. R. Clingeleffer and R. L. Correll. 2002. Rootstock effects on salt tolerance of irrigated field-grown grapevines (*Vitis vinifera* L. cv Sultana). 1. Yield and vigour inter-relationships. Austr. J. Grape Wine Res. 8:3-14.
Wildman, W. E. 1986. Phylloxera in Monterey County, California. I. Rate of spreading an advanced infestation. Amer. J. Enol. Vitic. 37:115-120.
Wolpert, J.A., D.R. Smart and M. Anderson. 2005. Lower petiole potassium contents at bloom in rootstocks with *Vitis berlandieri* genetic backgrounds. Amer. J. Enol. Vitic. 56 163-169

Table 1. Description of scion variety, year planted, data years, soil type and soil depth in research trial sites in the Sacramento Delta, Amador County and Sonoma County.

Experiment	**Sacramento Delta**	**Sacramento Delta**	**Amador County**
Scion variety	Chardonnay	Cabernet Sauvignon	Zinfandel
Year planted	1990	1990	1990
Data years	1995-97	1995-97	1995-97
Soil type	Egbert clay (sandy loam variant)	Tinnin loamy sand	Sierra coarse sandy loam
Soil depth (cm)	120	165	> 180

Table 2. Rootstocks and their parentage as utilized in rootstock trials in the Sacramento Delta and Amador County.

Rootstock	**Parentage**
St. George	*V. rupestris*
3309 Couderc	*V. riparia* x *V. rupestris*
101-14 Mgt	*V. riparia* x *V. rupestris*
110 Richter	*V. berlandieri* x *V. rupestris*
1103 Paulsen	*V. berlandieri* x *V. rupestris*
5BB Kober	*V. berlandieri* x *V. riparia*
5C Teleki	*V. berlandieri* x *V. riparia*
420 A Mgt	*V. berlandieri* x *V. riparia*
1616 Couderc	*V. solonis* x *V. riparia*
44-53 Malegue	*V. riparia* x (*V. cordifolia* x *V. rupestris*)
Ramsey (Salt Ceek)	*V. champinii*
Harmony	1613 C (op[z]) x *V. champinii* (op)
Freedom	1613 C (op) x *V. champinii* (op)
VR O39-16	*V. vinifera* x *M. rotundifolia*
140 Ruggeri	*V.berlandieri* x *V. rupestris*

[z] op = open pollinated seedling

Table 3. Effect of rootstock nitrate nitrogen content in leaf petioles of Chardonnay grapevines at bloom, veraison and harvest, Sacramento Delta (average of 1995 to 1997).

Rootstock	season			NO_3-Nitrogen (ppm)					
				bloom		Veraison		harvest	
	B	V	H						
5C	a	a	a	358	bcde	449	abcd	1099	ab
5BB	a	a	a	468	abcd	525	ab	961	abc
420A	b	b	a	244	de	583	a	1483	a
110R	b	b	a	547	abc	481	abc	1424	a
1103P	ab	b	a	701	a	379	bcde	901	abc
101-14	b	b	a	314	cde	324	cde	849	abc
3309	b	b	a	445	bcd	387	bcde	1002	ab
St. George	b	b	a	531	abc	429	abcd	1064	ab
44-53	b	b	a	139	e	319	cde	710	bc
1616	b	ab	a	127	e	231	e	353	c
O39-16	b	b	a	241	de	287	de	730	bc
Harmony	b	b	a	159	e	224	e	686	bc
Freedom	ab	b	a	537	abc	335	cde	931	abc
Ramsey	ab	b	a	592	ab	397	bcd	1065	ab
all stocks	b	b	a	386		382		947	

Table 4. Effect of rootstock on nitrate nitrogen content in leaf petioles of Cabernet Sauvignon grapevines at bloom, veraison and harvest, Sacramento Delta (average of 1995 to 1997).

Rootstock	season			NO$_3$-Nitrogen (ppm) bloom		Veraison		harvest	
	B	V	H						
5C	a	b	a	403	a	149	c	360	ef
5BB	a	a	a	595	a	263	bc	398	def
420A	b	ab	a	258	a	379	b	592	bcd
110R	a	b	ab	619	a	344	b	530	bcde
1103P	a	a	a	694	a	336	b	709	ab
101-14	a	a	a	457	a	262	bc	384	ef
3309	a	b	b	758	a	387	b	524	bcde
St. George	a	b	ab	774	a	276	bc	464	cdef
44-53	a	b	ab	390	a	116	c	288	f
1616	b	b	a	279	a	342	b	606	bc
O39-16	a	a	a	792	a	539	a	806	a
Harmony	b	b	a	430	a	366	b	674	ab
Freedom	a	b	ab	692	a	213	bc	400	def
Ramsey	a	a	a	799	a	339	b	610	bc
all stocks	a	b	a	567		307		525	

Table 5. Effect of rootstock on nitrate nitrogen content in leaf petioles of Zinfandel grapevines at bloom, veraison and harvest, Amador County (average of 1995 - 1997).

Rootstock	season			NO$_3$-Nitrogen (ppm) bloom		veraison		harvest	
	B	V	H						
5C	a	b	b	976	cde	53	c	63	de
5BB	a	b	b	2250	a	55	c	100	cd
420A	a	b	b	514	f	149	a	230	a
110R	a	b	b	890	ef	62	bc	45	e
1103P	a	b	b	1496	b	81	abc	123	bc
101-14	a	b	b	1252	bcde	86	abc	91	cd
3309	a	b	b	1356	bcd	98	abc	155	b
St. George	a	b	b	1588	b	36	c	34	e
44-53	a	b	b	825	ef	143	a	126	bc
1616	a	b	b	1006	cde	58	c	58	de
O39-16	a	b	b	2367	a	23	c	120	bc
Harmony	a	b	b	947	def	139	ab	96	cd
Freedom	a	b	b	1414	bc	48	c	61	de
Ramsey	a	b	b	1557	b	86	abc	132	bc
all stocks				1317		80		102	

Table 6. Values of Coefficients of Variability found in tissue samples from three sites and three varieties. Data are the mean of three years (1995 – 1997). Data are presented as the % relationship of the standard error to the mean [(std deviation /mean) x 100].

	Blades			Petioles		
	bloom	veraison	harvest	bloom	veraison	harvest
Potassium Total						
Delta Cabernet Sauvignon	3	5	8	8	11	18
Delta Cabernet Chardonnay	5	4	5	9	6	9
Montevina Zinfandel	4	5	7	8	11	15
Nitrogen Total						
Delta Cabernet Sauvignon	2	3	3	6	7	5
Delta Cabernet Chardonnay	2	2	3	4	4	6
Montevina Zinfandel	2	2	2	5	2	3
Nitrate						
Delta Cabernet Sauvignon	11	8	17	38	38	35
Delta Cabernet Chardonnay	9	10	18	30	29	40
Montevina Zinfandel	9	7	10	17	29	29

The Importance of Phosphorus Nutrition for Maintaining Vineyard Production and Fruit Quality Levels

Paul W. Skinner, Ph.D.
Terra Spase, Inc.
345 La Fata Suite D, St. Helena, CA 94574
Ph 707-967-8323 paulsts@earthlink.net

Abstract

Phosphorus deficiency was first recognized in California vineyards in 1983 (Cook et al). Subsequently soil P levels and P applications were correlated with vine tissue P levels, vine reproductive development, and yield responses in several wine grape cultivars (Skinner et al 1987, 1988, 1989). Furthermore, P was found to play a role in magnesium translocation from roots to shoots in vines growing on low pH and low P soils which also impacted vine photosynthesis, vegetative growth, and pruning weight (Skinner et al 1990). Wine chemistry and sensory analysis data also have shown significant effects due to P applied in vineyards. The importance of phosphorus nutrition to sustainable economic vineyard production and quality levels has been demonstrated in both wine and table grape vineyards and should be managed accordingly. Vine P deficiency symptoms and vine P nutrition problems can be found as a result of low soil phosphorus levels or other soil characteristics which inhibit rooting including high or low pH, low Ca/Mg ratio, shallow sandy soils or soils with restricted layers. Soil chemical and physical analyses and mapping of surface and subsurface conditions are currently being used to identify problem soils both before planting and in existing vineyards so that their limitations can be effectively removed. Maps of soil P levels, soil pH and soil Ca/Mg ratio can be combined into a soil zone map showing areas with high probability of response to P fertilization.

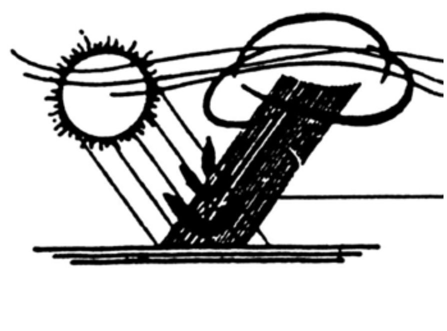
Session III

Innovation and Important Issues in Pest Management

Session Chairs:

Tom Babb, CA Dept. of Pesticide Regulation

Suduan Gao, USDA-ARS



Urban IPM Opportunities

Karey Windbiel-Rojas, Urban IPM Educator,
UC Statewide IPM Program
One Shields Avenue, University of California, Davis CA 95616
(530) 752-3941, kwindbiel@ucdavis.edu

Mary Louise Flint, Director, IPM Education and Publications,
UC Statewide IPM Program
One Shields Avenue, University of California, Davis CA 95616
(530) 752-7692, mlflint@ucdavis.edu

Introduction

Historically, agricultural activities have been assumed to be the major contributor to pesticide contamination of water bodies. However, in recent years, increased pesticide use and monitoring in urban areas has shifted some of the focus to contributions made by home and garden chemicals. Home and garden chemicals are polluting California's waterways, primarily due to residential use. Most home, garden, landscape and other urban pesticide use goes unreported in California, so the scope of the issue is largely unknown.

Opportunities exist to address some major environmental and health concerns and also improve efficacy of pest management efforts. Statewide, increased awareness of the impacts of urban pesticide use on water quality is leading many agencies to require use of alternative pest management practices. As more agencies promote integrated pest management (IPM) practices, there will be greater need for businesses and individuals with knowledge of IPM control tactics. Outreach programs to educate the urban population are also vital in reducing pesticide loads in the environment and reducing impairment of our water bodies. The UC Statewide IPM Program is moving forward to expand its programs to address these issues in partnership with others in UC and in the public and private sector.

Urban Pest Management Issues

An increasing number of California's population is urban or suburban as more of our agricultural landscape is developed into new homes and businesses, public parks and gardens, golf courses, and schools. With the increasing urban population comes the possibility for water quality impairment through residential activities, such as the management of pests in urban homes and gardens.

Urban use of pesticides is causing water quality problems statewide. Pesticide concentrations in many urban water bodies in California persist at levels exceeding federal and state water quality standards. In recent years, a number of home and garden pesticides have been found to cause environmental and health problems. Diazinon and chlorpyrifos are two such pesticides that were removed from the urban use market because they were discovered to cause mortality of several aquatic organisms, indicating poor water quality. Toxic levels of pyrethroid insecticides have recently found in urban stream sediments in a number of California cities and suburbs (Weston et. al. 2005).

Recent surveys of residential pesticide use in California suggest most residents do their own pest control. About 60-78% of residences reported outdoor pesticide applications—with the residents themselves made about half of these applications. Half these residents dispose of pesticides improperly, by either pouring them down storm drains or putting them in the trash (Flint 2003). Although more than half the people interviewed were aware that pesticides used around home and gardens affect water quality in local creeks, rivers and oceans, most had not changed their behavior to reduce problems.

Consumers can choose from hundreds of pesticide products on retail store shelves, but have no training and often few resources to turn to for help in making decisions. Whereas pesticide applications in agricultural areas are supervised by licensed professionals, home use requires no certification, training or continuing education.

Opportunities in Urban Areas

Communities, public agencies, school districts, homeowners and professional landscapers are all interested in ways to reduce the pesticide load in the environment. Residents are largely uninformed about pests and pesticides, and unlike in agriculture, home and garden pesticide use is not regulated or reported. Groups that do report pesticide use however are structural pest control operators, landscape maintenance professionals, and public agency pest control workers. An important link to reducing environmental impacts of residential pesticide use will likely be found through educating professional pest control practitioners on IPM (Kreidich et al. 2005).

Federal and state agencies have put forth guidelines and regulations that require many municipalities and school districts to utilize less toxic pest management alternatives. The California Healthy Schools Act of 2000 required that California schools post and report pesticide use and consider implementing IPM programs on school grounds. Many public agencies are developing IPM policies and many municipalities are considering restricted pesticide lists. Local agencies requesting IPM training for staff and contractors may continue to increase.

City and county water management agencies in California are required to protect water bodies from pesticide contamination. These cities, counties and water agencies are seeking information and new ways to solve the continuing threat to our waterways by urban pesticide use. Integrated Pest Management provides safer, effective alternatives for managing pests. Expertise in IPM issues will continue to be in great demand to help reduce pesticide use and implement IPM programs.

New and Emerging Pests

Combating new invading pests in California's urban areas is also an ongoing issue for pest management professionals. Recent pests that have had significant impact in the urban sector include the red imported fire ant, various eucalyptus pests (red gum lerp psyllid, eucalyptus long-horned borer and others), giant whitefly, glassy winged sharpshooter as well as a variety of invasive weed species. Loss and further regulation of many pesticides used in past decades to manage both agricultural, landscape, and structural pests has hampered management of many new and existing pests and increased the need for practitioners of IPM.

Current UC Resources
The University of California has many resources for those who seek pest management information. Numerous researchers at the campuses are addressing these issues as well as county Cooperative Extension personnel.

A key source of information in California for home and garden pest management information are the UC Master Gardener programs currently in 36 county University of California Cooperative Extension offices. The UC Statewide IPM Program is providing Master Gardeners with outreach materials and training to help them better respond to consumer questions. Volunteers in Master Gardener programs are involved in an array of activities to educate the public on IPM, water quality, and healthy gardening practices to protect people and the environment.

University of California Statewide IPM Program has many educational materials available for urban audiences, including residents, landscape professionals, maintenance gardeners, businesses, and public agencies. Resources include books, CDs and DVDs, consumer pest cards, and the informative Pest Notes series which focus on over 130 pests of gardens, landscapes, homes and structures. A new guide for landscape pest control professionals and a revised book for structural professions were released in 2006. The UC IPM website at www.ipm.ucdavis.edu is a comprehensive resource for information on how to identify and manage pests.

Enhancing our Outreach Programs for the Future
The studies by Flint (2003) and Kreidich et al. (2005) identified numerous educational initiatives that could significantly reduce environmental problems related to urban pest control.

For residential audiences:

- Better education about pesticide disposal.
- Promotion of environmentally sound ant management, since ant control accounts for a large portion of the most environmentally hazardous materials applied.
- Develop a certification or recognition program for professionals who are using environmentally sound methods.
- Educate retail store employees about pesticide safety and safer alternatives.
- Package pesticides in smaller containers.
- Make pesticide labels more useful and readable.
- Develop a consumer-friendly database of information related to safety and environmental problems associated with home use products.
- Encourage residents to use alternatives to risky pesticides. Provide more information on alternatives.
- Regularly update educational programs to account for new problem products and issues.

For professional audiences:

- Deliver IPM information in a clear, simple manner.
- Educate customers to demand IPM services.
- Educate groups who are not licensed about laws and regulations regarding pesticide use.
- Encourage private businesses and public agencies to adopt IPM programs and/or policies that encourage the minimal use of pesticides in and around their facilities.
- Develop an educational campaign about pesticide disposal and more readily accessible disposal sites.
- Take advantage of current pest control product vendors as an outreach channel.
- Develop a resource directory of IPM training materials and supplies for pesticide user groups.
- Produce an e-newsletter with unbiased information on IPM
- Develop IPM certification programs with incentives for companies to participate.

Over the coming years, the UC Statewide IPM Program in cooperation with others in UC Cooperative Extension and the public and private sector will be moving forward on many of these initiatives.

Literature Cited

Flint, M.L. 2003. Residential Pesticide Use in California: A Report of surveys taken in the Sacramento (Arcade Creek), Stockton (Five-Mile Slough) and San Francisco Bay Areas with Comparisons to the San Diego Creek Watershed of Orange County, California. California Department of Pesticide Regulation. Available on the web at http://www.ipm.ucdavis.edu/GENERAL/urbanpesticideuse.html

Kreidich, N. I., M. L. Flint, C. A. Wilen, and M. Zhang. 2005. Tracking non-residential pesticide use in urban areas of California. California Department of Pesticide Regulation. Available on the web at http://www.ipm.ucdavis.edu/GENERAL/urbanpesticideuse.html

Weston, D.P., R.W. Holmes, J. You and M.J. Lydy. 2005. Aquatic toxicity due to residential use of pyrethroid pesticides. Environ. Sci. Technology 39:9779-9784.

Options to Reduce Volatile Organic Compound Emissions from Pesticides

Randy Segawa, California Department of Pesticide Regulation
1001 I Street, Sacramento, California 95814
Phone (916) 324-4137, FAX (916) 324-4088, rsegawa@cdpr.ca.gov

Background

Many active as well as inert ingredients in pesticide products are volatile organic compounds (VOCs) and contribute to the formation of ozone, a major air pollutant in California. As required by the federal Clean Air Act, State Implementation Plans (SIPs) describe estimates of VOC emissions and how emissions will be reduced to achieve the ozone standard. Under the 1994 SIP, the Department of Pesticide Regulation (DPR) is required to track VOC emissions from pesticides and reduce them by specified amounts in five ozone nonattainment areas: Sacramento Metropolitan, San Joaquin Valley, Southeast Desert, Ventura, and South Coast. Pesticides are significant contributors to VOC emissions in certain nonattainment areas, particularly the San Joaquin Valley.

Estimates of Pesticide VOC Emissions

DPR maintains an inventory of VOC emissions from agricultural and commercial structural use pesticide products that are estimated by:

Emission = VOC fraction in product x amount of product applied

DPR maintains databases of both the VOC fraction (emission potential) and the amount of product applied. DPR uses several methods to estimate the VOC emission potential for individual pesticide products. The current best method is a laboratory test using thermogravimetric analysis. DPR calculates the amount of product applied using data from Pesticide Use Reports. In California, all people who apply pesticides to an agricultural site must file a Pesticide Use Report that includes the product applied, dated treated, location, commodity, amount, acreage, and other information. From the emission potential data and the pesticide use data, DPR calculates VOC emissions for all years, beginning with 1990. This emission inventory is updated each year as new pesticide use and emission data are compiled. The inventory focuses on the period between May and October, the peak ozone season, and the five nonattainment areas.

As of 2004, DPR meets its 1994 SIP obligations in the Sacramento Metropolitan and South Coast nonattainment areas, but not in the San Joaquin Valley, Southeast Desert, and Ventura nonattainment areas. VOC emissions in all areas show similar patterns. VOC emissions parallel pesticide use, with areas and years of high use corresponding to high VOC emissions, and vice versa. Fumigants and pesticides formulated as emulsifiable concentrates are major pesticide VOC sources, particularly in the three areas that do not meet the pesticide SIP goals.

Key Regulatory Issues

The emission inventory reveals some important regulatory issues. DPR was required to meet the VOC reduction goal for the San Joaquin Valley nonattainment area in 1999, and maintain the goal. While pesticide VOC emissions in the San Joaquin Valley declined for several years, and the goal was met in 2001, the goal has not been met for the last few years. In addition, the U.S. Environmental Protection Agency issued a more stringent ozone standard in 2004. California must develop a new SIP and further reduce VOC emissions from all sources in order to achieve the revised standard. DPR also continues to have concerns about exposures to fumigants and pesticide drift, in general. To address all of these issues, DPR began an air quality initiative in 2006.

Pesticide Air Quality Initiative

DPR's air initiative has three main goals:

- Reduce VOC emissions to meet existing SIP commitments by 2008.
- Develop a new SIP commitment in 2007.
- Reduce the human health risk from pesticide exposures.

DPR's air initiative has four main elements to achieve these goals:

- Reduce emissions from fumigants.
- Reduce emissions from emulsifiable concentrates.
- Develop pest management techniques with a focus on air quality.
- Introduce innovative technologies.

To address fumigants, DPR is developing regulations that will require certain low-emission application methods or prohibit certain high-emission application methods. Research has demonstrated that fumigant emissions vary with method of application. For example, deep injection of fumigants has lower emissions than shallow injection. Intermittent irrigation, less permeable tarpaulins, and other techniques also show lower emissions for certain fumigants, and may be required. The regulation may also include requirements for notification of neighboring properties, applications only by licensed pest control operators, and other restrictions.

To address emulsifiable concentrates, DPR is reevaluating more than 100 products for possible reformulation to reduce the VOC content. The median VOC content for emulsifiable concentrate products is approximately 40%, and some contain more than 90% VOCs. The goal is to reduce the VOC content of some of these products to 20%. DPR is also considering a VOC limit as a condition of registration for some new products.

DPR's activities for fumigants and emulsifiable concentrates are short-term measures to improve air quality. However, some long-term measures are needed to meet future obligations. These long-term measures will include pest management and innovative technologies. DPR plans to expand its efforts for strategic partnerships with agricultural commodity groups; support research on pest-resistant and tolerant crops; support pest exclusion; and create an inventory of application equipment that employs special nozzles, variable rate, remote sensing, or other advanced technologies. DPR is also considering other pest management elements, such as a best management practices evaluation as part of the restricted materials permit process, and a program to provide easier access to pest management information.

DPR conducted a series of workshops on the air initiative in 2006, and there will be additional workshops and opportunities for comment on all elements as DPR moves forward.

Methods to Reduce Fumigant Volatilization Losses from Agricultural Fields

Husein Ajwa
Extension Specialist, UC Davis
1636 East Alisal Street, Salinas, CA 93905
Phone (831) 755-2823, FAX (831) 755-2844, haajwa@ucdavis.edu

Suduan Gao, USDA-ARS, Water Management Research Laboratory,
9611 S. Riverbend Avenue, Parlier, CA 93648, sgao@fresno.ars.usda.gov

David Sullivan, Sullivan Environmental, 1900 Elkin Street,
Alexandria, VA 22308, sull_env@ix.netcom.com

Randy Segawa, Department of Pesticide Regulation, Sacramento, CA,
rsegawa@cdpr.ca.gov

Deb Shatley, Dow Agrosciences, Lincoln, CA 95648,
dgshatley@dow.com

Introduction

Fumigants are regulated in part based on air emissions. Predicted emissions (soil surface fluxes) and toxicology of the material are used by the California Department of Pesticide Regulations and the U.S. Environmental Protection Agency to establish application rates, buffer zones, and use limits (township caps). Use of 1,3-dichloropropene (Telone, InLine) in California is currently limited by township caps and buffer zones. Chloropicrin (Pic) and metam sodium are currently under re-registration and preliminary indications are that uses may be limited through the imposition of greater buffer zones. Counties are currently limiting application rates and setting buffers for these materials in anticipation of revised federal and state regulations.

Current methods of soil fumigation can result in unintended fumigant escape into the atmosphere. Inadequate sealing practices will reduce the efficacy of soil fumigants against soil pests and may cause off-site emissions. Tested emission reduction practices include deep injection, drip application (Ajwa et al., 2004), fumigant degraders such as thiosulfate (Wang et al., 2000), and the use of a range of low permeability tarps including virtually impermeable film (VIF) (Nelson et al., 2001). Although VIF has been shown to have extremely low permeability under laboratory conditions, success in reducing emissions and improving efficacy in broadcast shank fumigation has not been successful because the proper glue is not available. High soil water content reduces movement of alternative fumigants that tend to be much less volatile than methyl bromide. Application of a water seal at the soil surface has been shown to reduce emissions of fumigants (Sullivan et al., 2004). Consequently, the use of sprinklers to seal the soil surface can be a practical management option.

Reducing fumigant emissions into the atmosphere has become critical to ensure the continued availability of methyl bromide alternative fumigants. Our goal was to develop management practices that can significantly reduce fumigation emissions while achieving good soil pest control. Our research evaluated the use of VIF, semi-impermeable film (SIF), and sprinkler-applied water plus thiosulfate seal to reduce volatilization losses of 1,3-dichloropropene (1,3-D) and chloropicrin (Pic) after drip application of these fumigants to raised soil beds.

Sealing Treatments and Fumigants

Experiments were conducted in the coastal strawberry production areas. Each experiment was conducted simultaneously on four adjacent fields. Each field was one acre in size, and the four fields were separated from each other by >1000 ft to avoid cross contamination. The four fields contained the same soil type, soil moisture, drip tape, and were prepared following standard strawberry field preparation practices by cooperating growers. The four sealing treatments were: 1) standard high density polyethylene (HDPE), 2) standard HDPE plus 10 mm water seal containing 25 gal potassium thiosulfate, 3) VIF or SIF, and 4) VIF or SIF plus 10 mm water seal containing 25 gal potassium thiosulfate. A sprinkler system was used to apply the water plus thiosulfate seal immediately after drip fumigation with InLine or Pic.

Air Sampling

The Indirect Flux Method was used to estimate fumigant flux from the field. This method uses the Industrial Source Complex Short Term (ISCST3) model and an atmospheric dispersion model used by EPA for regulatory purposes. In this method, the fumigant concentrations in the atmosphere around the field are measured and used with the ISCST3 dispersion model to back-calculate the field emission rate. Volatilization flux measurements were obtained using air samplers (pumps) positioned at eight locations around each field (Figure 1). The air was sampled at a height of 1.5 m above the soil surface at 6 or 12 hour intervals for five days. Air concentration measurements were obtained by collecting fumigant on charcoal or XAD sampling tubes. The tubes were then extracted with solvent (ethyl acetate or hexane) and fumigant analysis was done by using a gas chromatography with an electron capture detector.

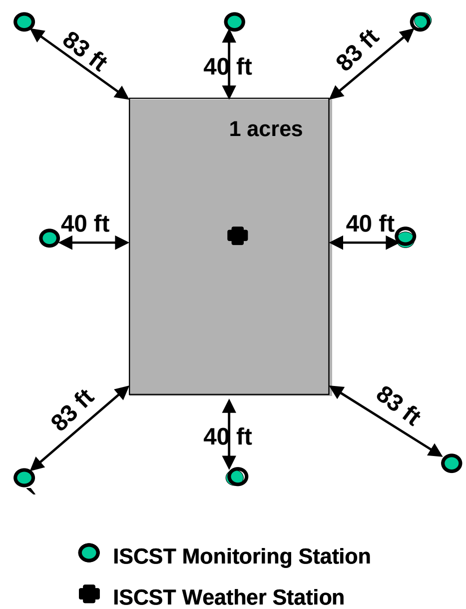


Figure 1. Locations of air sampling pumps (monitoring stations) and meteorological station for each field. The four fields have the same monitoring station set-up.

Emission Rates

Fumigant flux was estimated by using the ISCST3 dispersion method. In this method, the fumigant concentrations in the atmosphere around the field are measured and emission rates are back-calculated. For example, results computed using this dispersion model showed that the use of VIF or HDPE tarp plus thiosulfate seal reduced chloropicrin emissions by more than 40% relative to HDPE tarp alone (Figure 2). This presentation will discuss flux results for InLine applied under SIF plus thiosulfate. In addition, this presentation will compare fumigant emissions computed by using three techniques: 1) off-site indirect method, 2) closed chamber method, and 3) on-site micrometeorological method.

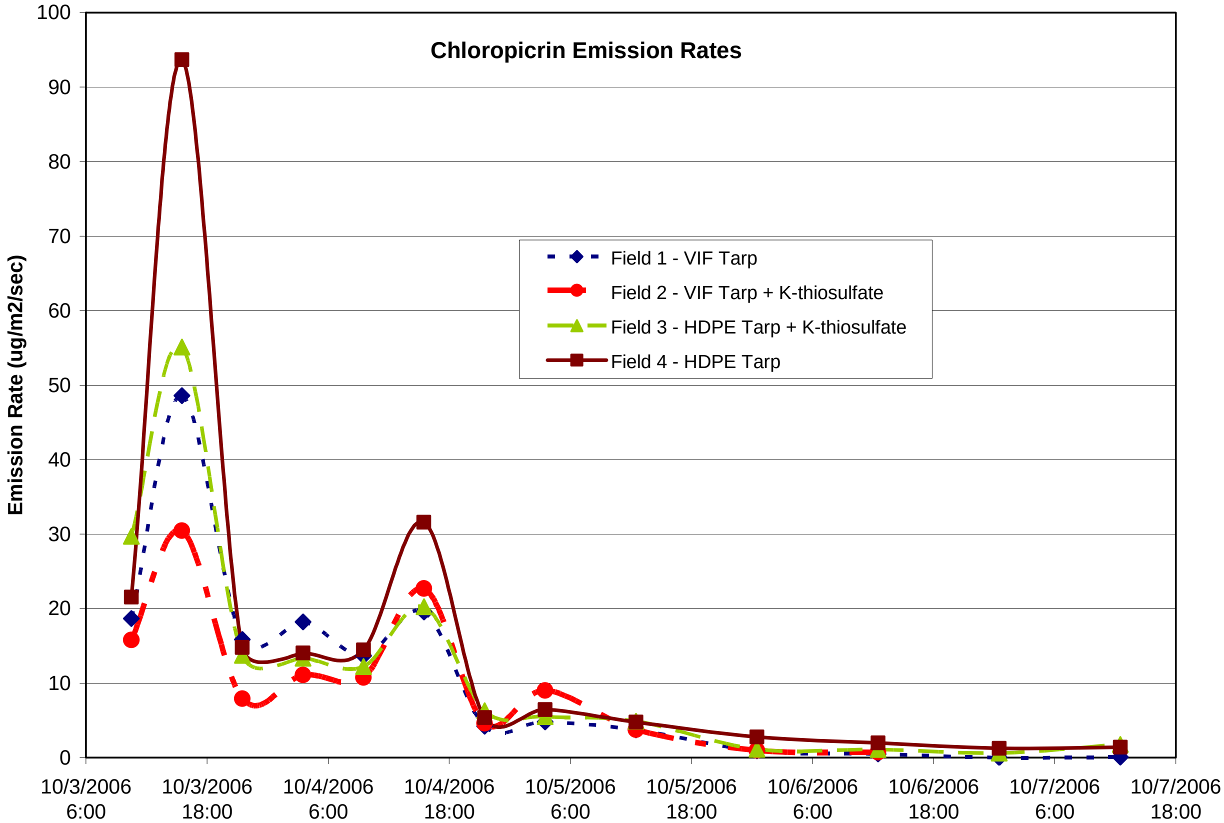


Figure 2. Chloropicrin emission rates (:g m^{-2} sec^{-1}) from four fields after drip application under two types of plastic tarp.

Although the low emission practices might increase application costs, lower emissions can provide an argument for reduced buffer zones or increased township caps. We believe that the proposed low emission practices are practical and affordable, compared to the alternative of not being able to use these fumigants.

Literature Cited

Ajwa, H.A., and T. Trout. 2004. Drip application of alternative fumigants to methyl bromide for strawberry production. HortScience 39:1707-1715.

Nelson, S.D., C. Riegel. L.H. Allen, Jr, D.W. Dickson, J. Gan, S.J. Locascio, and D.J. Mitchell. 2001. Volatilization of 1,3-dichloropropene in Florida plasticulture and effects on fall squash production. J. Am. Soc. Hortic. Sci. 2001; 126: 496-502.

Sullivan, D.A., M.T. Holdsworth, and D. J. Hlinka. 2004. Control of off-gassing rates of methyl isothiocyanate from the application of metam-sodium by chemigation and shank injection. Atmos. Environ. 38:2457-2470.

Wang, Q., J. Gan, S.K. Papiernik, and S.R. Yates. 2000. Transformation and detoxification of halogenated fumigants by ammonium thiosulfate. Environ. Sci. Technol. 34: 3717-3721. 2000.

Lodi Rules – Sustainable Pest Management Practices

Clifford P. Ohmart
Research/IPM Director, Lodi-Woodbridge Winegrape Commission
2545 West Turner Rd., Lodi CA 95242
Phone (209) 367 4727, FAX (209) 367 0737, cliff@lodiwine.com

Introduction

The Lodi-Woodbridge Winegrape Commission (LWWC) is a grower commission formed in 1991 by a vote of the winegrape growers in California Crush District #11. It is funded by an assessment on the annual value of growers' winegrape crops. There are currently about 750 LWWC member growers farming over 90,000 acres of winegrapes which comprises about 20% of the winegrape production in California. Lodi winegrape growers set three goals when the LWWC was formed:

1. Differentiate Lodi in the marketplace as a producer of premium winegrapes and wine.
2. Fund research on local viticulture issues assisting Lodi growers to produce higher quality winegrapes.
3. Create and implement an area-wide integrated pest management (IPM) program.

The IPM program has evolved through a series of stages with each stage forming a component of the program. The first component is grower outreach and was initiated soon after LWWC was established. It consists of several types of meetings, such as breakfast meetings, half day research seminars, and field days, as well as a bi-monthly newsletter and website (www.lodiwine.com).

The second component was initiated in 1996 with LWWC being award a Biologically Integrated Farming Systems (BIFS) grant from the University of California Sustainable Agriculture Research and Education program. While IPM is an integral part of biological farming, BIFS is a whole farm approach to management where a grower implements sustainable practices to manage their soil, water, and ecosystem around the vineyard as well as pests. The BIFS grant is a demonstration project where growers implement sustainable farming practices in specific vineyards designated as BIFS vineyards. All the activities done in the vineyards, such as pest monitoring, pesticide applications, fertilizer applications, canopy management activities, floor management activities and yields, are recorded in a state of the art database and the results are summarized each year and shared with the participating growers. Furthermore these vineyards serve as sites for field days for all Lodi growers to come and observe the results of implementing specific sustainable practices. There are 45 growers and 70 vineyards in the BIFS program. Ohmart (2006) published a recent summary of the program.

The third component was initiated in 2000 with the publication of the *Lodi Winegrower's Workbook: A self-assessment of integrated farming practices* (Ohmart and Matthiasson 2000). Growers use the workbook to: 1) Identify the good things there are doing in their vineyards; 2) Identify areas of concern in their practices either from an environmental or crop quality perspective; 3) Create an action plan to address these concerns; and 4) Develop a time table for carrying out this action plan. Over 350 Lodi winegrape growers have filled out the workbook at least once. Furthermore, the *Lodi Winegrower's Workbook* has served as a model for a workbook that was developed for the entire California wine community (Dlott et al. 2002), as well as for wine communities in other states such as Washington and New York.

The fourth component, which is the topic of this presentation, was initiated in 2005 and is a coming together of LWWC's goals #1 and #3. It is *The Lodi Rules for Sustainable Winegrowing* program, which is California's first third party-certified sustainable winegrowing program (Ohmart et. al. 2006; www.lodirules.com).

Program Description

What are *The Lodi Rules for Sustainable Winegrowing*? They are California's first sustainable winegrowing standards that have been peer reviewed by scientists, academics and environmentalists and being implemented on a region-wide basis. Participating growers can get their vineyards certified as producing sustainably-grown winegrapes. It is a third party certification program which means the standards have been reviewed and endorsed by an organization not connected to LWWC and verification of adherence to the farming standards is achieved by an auditing process overseen by the third party organization. Protected Harvest, a non-profit organization that independently certifies that growers are using stringent environmental growing standards, is the certifier for *The Lodi Rules* program (www.protectedharvest.org). Protected Harvest has received Consumers Union's highest ranking for an eco-label organization (www.ecolabels.org).

The Lodi Rules program has two components; sustainable winegrowing practices standards, and a Pesticide Environmental Assessment System (PEAS) that measures the environmental impact of all the pesticides used in a vineyard during the year. To qualify for certification a vineyard has to achieve a minimum number of sustainable farming practices points**,** and not exceed a maximum number of pesticide impact points calculated using PEAS. Certification is awarded to an individual vineyard on an annual basis. Protected Harvest ensures compliance and chain of custody with *The Lodi Rules* using an auditing process.

***The Lodi Rules* farming practice standards**

The Lodi Rules farming practices standards are based on the *Lodi Winegrower's Workbook* (Ohmart and Matthiasson 2000). A farming practice has to meet three criteria to be included as a standard:

1. It must be measurable, in other words there must be physical evidence indicating the practice was carried out.
2. The practice must maintain or enhance one or more of the 3 E's of sustainability, those being Economic viability, Environmental soundness, and social Equity, or responsibility.
3. The practice must be technically and economically feasible, and must not set an unachievable standard.

The Lodi Rules consist of 75 farming practice-standards divided into six chapters: Ecosystem management; Education, Training and Team Building; Soil Management; Water Management; Vineyard Establishment; and Pest Management. They encompass all aspects of quality winegrape production. The standards were draft by a 22-member committee which included ten LWWC growers, two Lodi winery representatives, two pest control advisors, a wildlife biologist, two University of California (UC) Viticulture Farm Advisors, a UC Irrigation Specialist, and four LWWC staff. Managers of small, medium, and large vineyard operations were asked to serve on the committee to ensure that all types of Lodi growers were represented. Furthermore, over 30% of the vineyard acres in LWWC are managed by growers on the certification committee.

The draft standards were submitted to Protected Harvest which then organized a scientific peer-review followed by a Protected Harvest Board review. The standards were revised based on reviews and given unanimous Board endorsement in May 2005. A complete copy of the farming practices standards can be downloaded from: http://www.lodiwine.com/4_3_The_Lodi_Rules_for_Sustainable_Winegrowing_standards.pdf.

IPM is the foundation of the pest management chapter of *The Lodi Rules* farming practices standards. There are 18 pest management farming practice standards addressing the following topics: pest monitoring, economic thresholds for key pests, monitoring for natural enemies using the results in decision-making, use of cultural practices for key vineyard pests including vertebrate pests, and training of employees in pest recognition. Furthermore the grower is required to develop management plans for the following: economic threshold plans for key pests, powdery mildew, weeds, soil borne pests, vertebrates, spray/dust drift, and sprayer maintenance and calibration.

The Pesticide Environmental Assessment System

One unique aspect of *The Lodi Rules* program is the use of a pesticide environmental impact model, the Pesticide Environmental Assessment System (PEAS), in determining whether a vineyard qualifies for certification. Environmental impact models have been developed as tools to quantify the environmental impact of pesticides (Ohmart et al. 2006).

Because of the process used by the U.S. Environmental Protection Agency to register pesticides, extensive data are available on toxicity and environmental impacts of pesticide active ingredients commonly used in agriculture. However, the data is not readily available to most farmers and pest management specialists, and rarely plays a role in guiding the selection of pesticides used in the field. To make these data more useful to growers, commodity groups, food companies, and IPM advisors experts have created pesticide environmental impact models. American Farmland Trust published a description and comparison of eight of these models (http://www.aftresearch.org/ipm/risk.htm).

The basic PEAS metric is calculated by multiplying the pounds of a pesticide applied by its toxicity factor. The toxicity factor incorporates use rates in estimating per acre toxicity units, it also strives to take into account, to the extent possible, factors impacting likely levels of exposure based on where, when, and how a pesticide is applied. This process leads to a set of use-specific Use Pattern Adjustment Factors (UPAFs). For example, an in-season, liquid foliar application is assumed to pose the highest potential exposure for workers and most non-target organisms, and corresponds to a use pattern adjustment factor (UPAF) value of 1.0 (no downward adjustment in expected exposure levels). A change in use pattern to, for example, a pre-plant soil-incorporated granular application, would result in a UPAF of 0.2, reflecting the lessened potential for exposure to workers. Accordingly, PEAS is designed to rank relative risks taking into account factors impacting exposure levels.

Pesticide risk can arise from multiple routes of exposure (for people, via food, water, dermal, or inhalation exposure). Some exposures are short-term in nature (acute risks), and others occur steadily over a long period of time (chronic risks).

The Lodi Rules PEAS model currently contains five component indices measuring:

- worker acute risks
- dietary risks to people from acute and chronic exposure
- acute risks to small aquatic invertebrates
- acute risks to birds
- acute risks to bees and pest natural enemies

Each of these indices is used independently to assess relative risks to a specific class of organisms on a per acre treated basis. For *The Lodi Rules* program, PEAS is used to calculate multiattribute risks spanning all of the above five indices. Because the certification committee felt that all five indices were equally important, the PEAS model weighs them equally.

The PEAS model was used to calculate pesticide environmental impact for each formulation of pesticide used in Lodi vineyards. Calculations were based on pesticide use in San Joaquin and Sacramento County vineyards; data on rates were obtained from the California Department of Pesticide Regulation's Pesticide Use Reporting database for 1999 to 2001(http://www.cdpr.ca.gov/docs/pur/purmain.htm). Pesticide use data were also obtained from LWWC's BIFS database which has monitored full pesticide use in 70 vineyards throughout California Crush District #11 from 1995 to present.

First, pesticide environmental impact units were calculated for one pound of each pesticide active ingredient. These values were then adjusted in accord with the applicable Use Pattern Adjustment Factor (UPAF), in order to make estimates of environmental impacts per acre treatment reflect the impacts on exposure of the specific formulation, treatment timing, method of application (such as soil-applied, ground-applied, aerially-applied), and the target site (foliage, soil, etc.). The results were then converted to impact indices for the commonly used unit of each formulated pesticide. A complete list of PEAS impact units for the pesticides registered for use in Lodi vineyards can be downloaded from:
http://www.lodiwine.com/5_2_Pesticide_Impact_Units_for_Registered_Pesticides.pdf.
Table I presents the calculation of total environmental impact units for pesticides applied to a representative Lodi vineyard for the entire season of 2004.

Table I. PEAS Model Environmental Impact Units calculation for a "representative" Lodi vineyard for 2004

Input Date	Chemical Name	Rate/Acre	Units	lbs AI* /Acre	Impact Index/lb AI	Impact Units/Acre
4/13/2004	Sulfur dust	15	lbs	14.70	0.157	2.31
4/22/2004	Sulfur dust	15	lbs	14.70	0.157	2.31
5/3/2004	Sulfur dust	15	lbs	14.70	0.157	2.31
5/13/2004	RoundUp Ultra Dry	0.92	lbs	0.66	0.328	0.06
5/16/2004	Sulfur dust	14	lbs	13.72	0.157	2.15
5/29/2004	Sulfur dust	15	lbs	14.70	0.157	2.31
6/2/2004	Rally 40W	3.88	ozs	0.10	3.137	0.30
6/24/2004	Provado Solupak 75% WP	0.63	ozs	0.03	116.28	3.44
6/24/2004	Acramite 50 WS	0.87	lbs	0.44	1.64	0.71
6/24/2004	Pristine	11.49	oz	0.26	0.75	0.20
7/28/2004	Gramoxone Max**	1	pints	0.52	0.32	0.05
7/31/2004	RoundUp Ultra Dry**	0.63	lbs	0.45	0.328	0.04
Total Impact Units for Season:						**16.20**

***AI = Active Ingredient**

****Herbicide was applied to 1/3 of vineyard acres so Impact Units were calculated accordingly**

Certification

A Lodi vineyard qualifies for certification if it meets two criteria. First, the farming practices used in the vineyard must achieve a score of 50% or better for each chapter of *The Lodi Rules*. Scoring below 50% on any chapter, even if the scores are very high on all the others, disqualifies the vineyard from certification. Second, the environmental impact units for the pesticides used in that vineyard for the year, calculated by *The Lodi Rules* PEAS model, cannot exceed 50 units.

The vineyard must qualify for certification each year. An independent auditor visits the vineyard to ensure compliance with *The Lodi Rules* and, using *The Lodi Rules* PEAS model, verifies that pesticides used in the vineyard for the year have not exceeded the environmental impact unit threshold. A grower joining *The Lodi Rules* program pays a sign-up fee that also covers the first year of certification. In subsequent years, an annual application fee is required, which is less than the sign-up fee. There is also an annual dollar fee per acre of vineyard seeking certification. The fees pay for administration and auditing of the certification program by Protected Harvest.

Lodi growers chose Protected Harvest as the third party certifier of *The Lodi Rules* program. This decision was based on several important factors. First, Consumer's Union gives Protected Harvest its highest report card rating for a third party certifying organization[1]. Second, to achieve endorsement by Protected Harvest the sustainable farming standards must pass a scientific peer review process as well as a Protected Harvest Board review. Last but not least, we liked the two components that make up the requirements for achieving Protected Harvest/Healthy Grown certification, farming practices as well as assessing the environmental impact of pesticides used in the vineyard.

Literature Cited

Dlott, J., Ohmart, C. P., Garn, J., Birdseye, K. and Ross, K., eds. 2002. The Code of Sustainable Winegrowing Practices Workbook. Wine Institute & Calif. Assoc. Winegrape Growers. 477pp.

Ohmart, C. P. 2006. Ten Years of the Lodi-Woodbridge Winegrape Commission's Biologically Integrated Farming Systems Program. http://www.lodiwine.com/SAREP_Newsletter_long_article_FINAL.pdf

Ohmart, C. P. and Matthiasson, S. K. 2000. Lodi Winegrower's Workbook: A self-assessment of integrated farming practices. Lodi-Woodbridge Winegrape Commission. 135pp.

Ohmart, C. P., Storm C. P., and Benbrook. C. M. 2006. Lodi Rules certification advances sustainable viticulture. Practical Winery & Vineyard 27(6):7-23.

[1] www.ecolabels.org

Session IV

What is in the Irrigation Toolbox

Session Chairs:

Blake Sanden, UCCE, Kern County

Charles Krauter, CSU Fresno

Estimating Crop ET: using CIMIS and new ET studies

Richard L. Snyder, Harry L. Carlson, Daniel S. Munk, Neil V. O'Connell, Donatella Spano, Pierpaolo Duce
Dept. of Land, Air and Water Res., University of California, One Shields Ave., Davis, CA 95616
Phone (530) 752-4628, rlsnyder@ucdavis.edu

Introduction

Evapotranspiration (ET_c) of well-watered crops can be estimated as the product of reference evapotranspiration (ET_o) and a crop coefficient (K_c) factor, where ET_o accounts for the weather effects on ET_c and the K_c factor accounts for differences between ET_c and ET_o. Crop coefficient factors are calculated as the ratio ET_a/ET_o using measurements of ET_a and estimated ET_o for the same time period; assuming that the crop is well-watered (i.e., $ET_c = ET_a$). In this paper, we discuss the estimation of sensible heat flux density (H) using the surface renewal (SR) method and the estimation of ET_a from H and measured net radiation and soil heat flux density.

Theoretically, ET_o represents the evapotranspiration of a virtual, short canopy of a well-watered, vegetated surface with specified canopy and aerodynamic resistances. In practice, however, ET_o is an estimate of the evapotranspiration of a broad expanse of 12 cm tall, cool-season grass (i.e., an irrigated pasture). A standardized ET_o equation, which uses either daily or hourly weather data was presented in ASCE-EWRI (2005) as:

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma \dfrac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)} \qquad (1)$$

where Δ is the slope of the saturation vapor pressure at mean air temperature curve (kPa $^{o}C^{-1}$), R_n and G are the net radiation and soil heat flux density in MJ $m^{-2}d^{-1}$ for daily or MJ $m^{-2}h^{-1}$ for hourly data, γ is the psychrometric constant (kPa $^{o}C^{-1}$), T is the daily or hourly mean temperature (^{o}C), u_2 is the mean wind speed in m s^{-1}, and $e_s - e_a$ is the vapor pressure deficit (kPa). The output units from Equation 1 are in mm d^{-1} for the daily and mm h^{-1} for the hourly time steps. For the daily data, R_n is input in MJ $m^{-2}d^{-1}$ and G is assumed to be zero. For the hourly calculations, R_n is input in MJ $m^{-2}h^{-1}$ and G is assumed equal to 10% of R_n when $R_n \geq 0$ and G is equal to 50% of R_n when $R_n < 0$. The C_n coefficients are 900 for daily and 37 for hourly calculations. The C_d coefficients are 0.34 for daily and 0.24 (daytime) and 0.96 (nighttime) for hourly time steps. Excel programs to compute ET_o values are available from http://biomet.ucdavis.edu. Note that CIMIS uses a different method to determine ET_o, but the difference from the ASCE-EWRI (2005) equation is small (Ventura et al., 2001).

The surface renewal (SR) method has shown promise to provide estimates of H regardless of the stability conditions and without the need for wind speed profile measurements (Paw U and Brunet, 1991). Because it does not rely on flux gradient theory, the fetch requirement is less, and there are fewer problems with measurement on slopes. When located in or near a plant canopy, air parcels heat or cool as sensible heat exchanges with canopy elements. Under unstable conditions, cool air sweeps into a canopy from above and the air parcels are gradually heated by the canopy elements. Therefore, temperature plots drop sharply as cold air enters the canopy and they show a slow rise as the air is heated. Then the warmed air ejects from the canopy as cool air again sweeps in from above. Under stable atmospheric conditions, the pattern is reversed as heat is transferred from warmer air to a cooler canopy. Temperature plots show ramp-like characteristics and the mean amplitude (a) and inverse ramp frequency duration

(d_r) can be quantified using structure function analysis (Van Atta, 1977). Paw U et al. (1995) showed that an expression for H can be derived from the conservation of energy:

$$H = \alpha H' = \alpha\left(\rho C_p \frac{a}{d_r} z\right) \quad (2)$$

where z is the measurement height (m), ρ is the air density (kg m^{-3}) and C_p is the specific heat of the air (J kg^{-1} K^{-1}). The factor H' is the SR sensible heat flux density assuming uniform heating from the ground up to the measurement height (z) and α accounts for unequal heating of the air volume under the temperature sensor (Paw U et al., 1995). The α factor is determined by calculating the slope of the linear regression (through the origin) of H from an accurate independent method such as eddy-covariance using a sonic anemometer versus H' (Snyder et al., 1996; Spano et al., 1997; Spano et al., 2000). Using H values from SR analysis with measured net radiation (R_n) and soil heat flux density (G), latent heat flux density (LE) is calculated as the residual of the energy balance equation:

$$LE = R_n - G - H \quad (3)$$

In this paper, we discuss several examples where the SR method was used to estimate ET_a and to determine K_c factors.

Methods and Materials

Field experiments were conducted over cotton with maximum canopy height h_c = 0.75 m in the San Joaquin Valley near Five Points, CA, over an onion crop, with h_c = 0.3 m, near Tulelake, CA, and over a Valencia orange orchard with h_c = 4.5 m near Lindsay, California. In all of these experiments, there was extensive fetch, the surface was relatively flat, and the crops were well irrigated. The cotton was furrow irrigated, the onion crop was irrigated with solid set sprinklers, and the orange orchard was irrigated with micro-sprinklers. For details on crops, soils, and instrumentation setups, see Snyder and O'Connell (2006) for the orange orchard and Munk et al. (2004) for the cotton crop.

Net radiation was measured with Q7.2 net radiometers and HFT3 heat flux plates from REBS, Inc. Soil temperature was measured with 'Tcav' soil averaging thermocouples (Campbell Scientific, Inc.). In each experiment, net radiation was measured at 1.0 to 1.5 m above the maximum canopy height. For the orange trees, the net radiometers were mounted above the edge of a row with a view that well represented the relative cover of foliage and ground. In all experiments, the heat flux plates were inserted horizontally at either 4 or 5 cm depth and the soil temperature sensors were used to obtain a spatially averaged temperature between the flux plates and the surface. For the orange orchard, a heat flux plate and soil temperature sensor transect between two rows was collected to obtain a weighted mean heat flux density for the crop. The soil heat flux density at the surface was estimated following the procedures in de Vries (1963).

High-frequency temperature data were collected using two 76.2 μm diameter junctions of chromel-constantan thermocouples using a frequency of 4 Hz for all of the experiments. In all experiments, the two thermocouples were mounted with the junctions about three 0.03 m apart. For the field crops, SR values of H' were determined separately for each thermocouple, and the mean H from the two readings was used to calculate LE. For the orange crop, the two thermocouples were wired in parallel, so only one value of H was recorded. Relative to the ground surface, the thermocouples were mounted at z = 1.5 m over cotton, z = 1.0 m over onions, and z = 4.5 m over the orange orchard. The orange orchard had east-west rows, and the thermocouples were mounted at 4.5 m height and oriented with the junction slightly north of the row center between two trees. The closest foliage to the thermocouple junctions was about 1.0 m distance. The second, third and fifth moments of temperature differences using 0.25 and 0.5 s time lags were computed and the means stored in a CR10X data logger (Campbell Scientific, Inc.) at the end of each half hour. The data were downloaded to a laptop computer and were analyzed following the procedures in Snyder et al. (1996) to estimate *H'*.

The eddy covariance *H* was determined using a 1-dimensional sonic anemometer and a 21X datalogger (Campbell Scientific, Inc). The data were collected at 5 Hz and the mean of three 10 minute values of the covariance between vertical wind speed fluctuations and temperature fluctuations about their means were computed. The mean of the three 10-minute samples was archived each half hour. The sonic anemometers were mounted at about the same height as the SR thermocouples. The SR *H'* data were compared with sonic anemometer *H* measurements to determine the α factor. *LE* was then determined using $H = \alpha H'$ and equation 2. The *LE* calculations were done on a half-hourly basis, and the daily energy fluxes due to R_n, G and *LE* are computed. Then the mean ET_c for an hour (J m^{-2} s^{-1}) was divided by the latent heat of vaporization (L = 2.45 J g^{-1}) and multiplied by 3.6 to obtain the depth of evaporated water (mm h^{-1}).

Reference evapotranspiration (ET_o) was calculated using hourly CIMIS weather data from the Westside Field Station (cotton), Tulelake (onions), and Lindcove (oranges). The hourly standardized ET_o equation (Eq. 1) was used to compute ET_o. Daily total ET_o (mm d^{-1}) was computed by summing 24 hourly values. The crop coefficients were computed from daily ET_a and ET_o as $K_c = ET_a/ET_c$.

Results and Discussion

After calculating *H'*, the α factor in Eq. 2 was determined by computing a linear regression through the origin of *H'* versus *H* from the eddy covariance measurements (Table 1).

Table 1. Linear regression statistics of half-hourly *H* from eddy covariance versus *H'* from surface renewal by crop. Slopes were forced through the origin.

Crop	Collection Dates	Slope (α)	R^2	n
Onions	15 Jun – 1 Sep 04	0.53	0.87	802
Cotton	10 Jul – 26 Jul 01	0.33	0.88	532
Orange Orchard	9 Jun – 19 Jun 03	0.47	0.84	423
Orange Orchard	13 Aug – 20 Aug 03	0.50	0.77	221

Onion Crop: Figure 1 shows four days of energy balance data measured over onions during the period 15-19 July 2005. Although the net radiation and soil heat flux density data were nearly the same on all four days, the ET_a increased dramatically on 17 July due to an irrigation event. Because there was more water available for evaporation, the sensible heat flux density was considerably more negative during the afternoon following the irrigation. Since the crop was irrigated fairly frequently, it is doubtful that the onions experienced water stress. Therefore, the increase in ET_a following irrigation was most likely due to increased soil surface evaporation. The ratio of *LE* to R_n - G was about 1.19 for the onion crop, which implies that considerable advective energy from the air was contributing to ET_a in the Tulelake region.

Cotton Crop: Figure 2 shows four days of energy balance data measured over Upland cotton during the period 17-21 July 2001. Again, the net radiation and soil heat flux density data were nearly the same on the four days. In this example, the ET_a was higher on 18 July than on 17

July because of increased wind speed on the second day. Then, the ET_a increased dramatically on

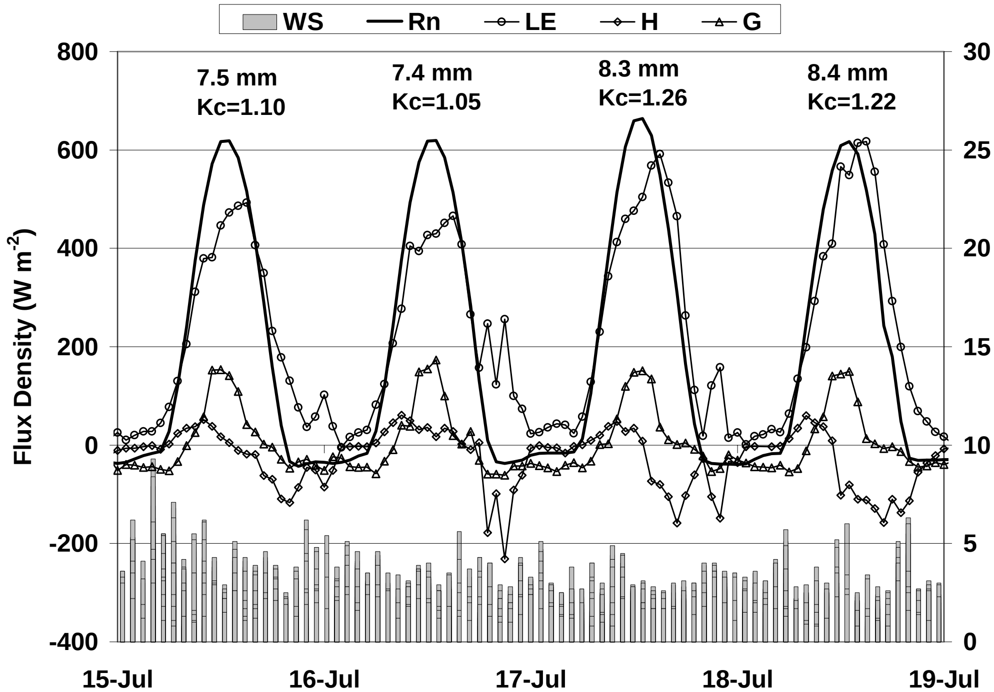


Figure 1. A sample energy balance trend and wind speeds during the period 15-19 July 2005 for an onion crop grown near Tulelake, CA with the ET_a and K_c values indicated. The crop was irrigated on 17 July.

19 July due to an irrigation event. The wind speed was considerably lower during the afternoon of 19 July than on 18 July, but the ET_a was much higher because the crop was not stressed after irrigation. The effect of the irrigation is apparent in the sensible heat flux data, which became negative in the afternoon following irrigation. The ratio of LE to $R_n - G$ was about 1.04 during the four days, which implies there was some additional energy supplied for ET from advection.

Orange Orchard: Figure 3 shows four days of energy balance data measured over a mature Valencia orange orchard during the period 30 June - 4 July 2003. Every second row of the orchard was irrigated for 48 hours starting on 2 July, and there was little effect of watering on the ET_a and K_c during the irrigation. The net radiation and soil heat flux density data were nearly the same on the four days, but the net radiation was considerably higher than for either the onion or the cotton crops. The ratio of LE to $R_n - G$ was about 0.84, during the four days. Recall that this ratio was about 1.04 for cotton and about 1.19 for onions. The net radiation showed peaks near 770 W m^{-2}, whereas ET_o had peak R_n near 650 W m^{-2}. The K_c factor averaged slightly higher than $K_c = 1.00$, which was considerably higher than the $K_c = 0.67$, which has traditionally been used for citrus. We believe that the difference is due to a change in the irrigation method from infrequent surface irrigation to high frequency irrigation with micro-sprinklers. In the experimental orchard, Every second row was watered in an irrigation set with half of the orchard receiving about 62.4 mm (2.5 inches) depth of application about every 5 or 6 days during the summer.

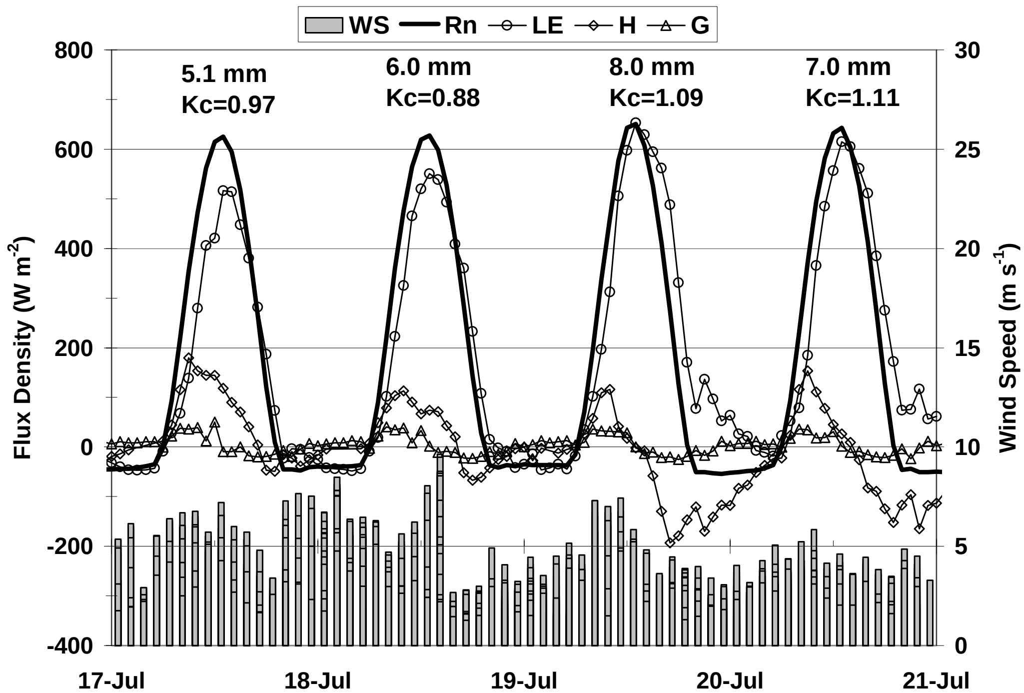


Figure 2. A sample energy balance trend and wind speeds during the period 17-21 July 2001 for Upland cotton grown near Five Points, CA with the daily ET_a and K_c indicated. The crop was irrigated on 19 July.

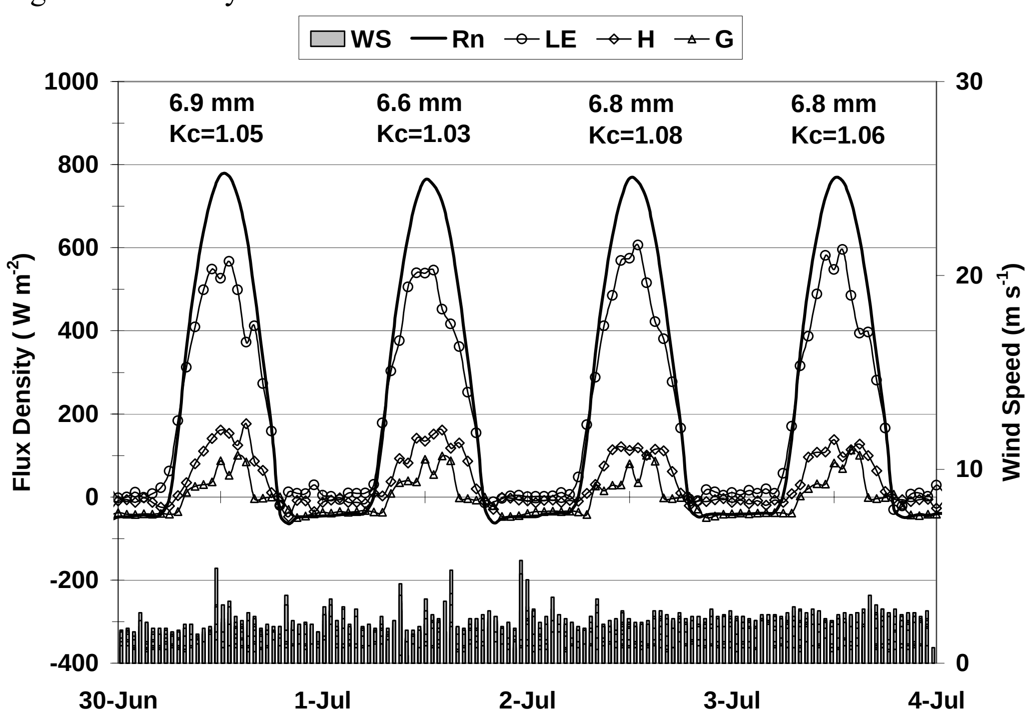


Figure 3. A sample energy balance trend and wind speeds during the period 30 June - 4 July 2003 for Valencia orange orchard with the daily ET_a and K_c values indicated. The crop was irrigated for 48 hours starting on 2 July.

Conclusions

The surface renewal method was used to estimate sensible heat flux density (H), and the H data were entered into an energy balance equation with measured net radiation and soil heat flux density to determine latent heat flux density and ET_a. Daily ET_o and ET_a totals were used to determine K_c factors for onion, cotton, and Valencia Orange crops during mid-season of the three crops. Crop coefficient factors were about $K_c = 1.16$ for onions, $K_c = 1.02$ for cotton, and $K_c = 1.05$ for oranges. While the K_c for cotton was similar to the $K_c = 1.05$, which is commonly used, the K_c values were quite different from the widely-used $K_c = 0.90$ for onions and $K_c =0.67$ for orange orchard. Irrigation timing influenced the ET_a rates of the onion and cotton crops, but the effect of irrigation on citrus was not evident. While the ratio of LE to $R_n - G$ was 1.19 for onion and 1.04 for cotton, it was only 0.84 for the orange orchard. A ratio higher than 1.0 implies that advective energy contributed to evapotranspiration. The low ratio of LE to $R_n - G$ for the orchard was expected due to the well-known stomatal control in citrus. The relatively high K_c value for the orchard was attributed to the much higher observed net radiation. The commonly used, low K_c values for citrus were developed more than 4 decades ago when trees were considerably smaller and infrequently irrigated by furrows, so the higher K_c factors for trees watered with high-frequency micro-sprinkler irrigation seems reasonable.

Literature Cited

ASCE-EWRI. 2005. *The ASCE Standardized Reference Evapotranspiration Equation*. Technical Committee report to the Environmental and Water Resources Institute of the American Society of Civil Engineers from the Task Committee on Standardization of Reference Evapotranspiration. 173 p.

De Vries, D.A. 1963. Thermal properties of soils., *in:* W.R. van Wijk (ed). *Physics of Plant Environment.* Amsterdam, The Netherlands: North-Holland Publishing Co. pp. 210-235.

Munk, D.S., Wroble, J., Snyder, R.L., Robb, J. and Hutmacher, R. 2004. Comparative Evaluation of Pima and Upland Cotton Transpiration in the San Joaquin Valley. Acta Horticulturae 664: 419-422.

Paw U, K.T. and Y. Brunet. 1991. A surface renewal measure of sensible heat flux density. Proc. of the 20th Conference on Agriculture and Forest Meteorology, Salt Lake City, pp. 52 - 53.

Paw U, K.T., J. Qiu, H.B. Su, T. Watanabe and Y. Brunet. 1995. Surface renewal analysis: a new method to obtain scalar fluxes without velocity data. Agr. & For. Met. 74: 119 - 137.

Snyder, R.L. and N.V. O'Connell. 2006. Crop coefficients for micro-sprinkler irrigated, clean-cultivated mature citrus in an arid climate. J. Irrig. and Drain. Eng. (in press).

Snyder, R.L. and W.O. Pruitt. 1992. Evapotranspiration Data Management in California, Proc. of Water Forum '92 - Irrig. & Drain. Session, ASCE, New York, N.Y.

Snyder R.L., D. Spano, and K.T. Paw U. 1996. Surface Renewal analysis for sensible and latent heat flux density. Boundary-Layer Met. 77: 249 - 266.

Spano D., R.L. Snyder, P. Duce, and K.T. Paw U. 1997. Surface renewal analysis for sensible heat flux density using structure functions. Agr. & For. Met. 86: 259 - 271.

Spano D., R.L. Snyder, P. Duce, and K.T. Paw U. 2000. Estimating sensible and latent heat flux densities from grapevine canopies using surface renewal. Agr. & For. Met. 104: 171-183.

Van Atta, C.W. 1977. Effect of coherent structures on structure functions of temperature in the atmospheric boundary layer. Arch. of Mech. 29: 161-171.

Ventura, F., B.A. Faber, K. Bali, R.L. Snyder, D. Spano, and P. Duce, and K.F. Schulbach. 2001. Model for estimating evaporation and transpiration from row crops. J. of Irrig. and Drain. Engng. 127(6): 339-345.

An Overview of Smart Water Application Technologies™ (SWAT™) and Achieving High Water Use Efficiency

David F. Zoldoske
Director, The Center for Irrigation Technology
California State University, Fresno

Introduction
The development of Smart Water Application Technologies™ or SWAT™ was initiated by water purveyors who wanted to improve residential irrigation water scheduling. It is estimated that typical residential landscapes apply 30 to 40% more water than is required by the plants. The hope is that the widespread adoption of "smart" controllers and soil moisture sensors would conserve a significant portion of the excess water applied.

Most in-ground irrigation systems are operated by a controller. The basic design of these controllers requires frequent input from the operator (homeowner) to adjust irrigation run times during the year. It has been noted that much of the over-irrigation occurs during the fall of the year when plant/water demand is dropping off and the corresponding irrigation run times are not reduced accordingly.

SWAT™ is a national initiative designed to achieve exceptional landscape water use efficiency through the use of irrigation technology. SWAT™ identifies, researches, and promotes technological innovations and related management practices that advance the principles of efficient water use.

"Smart" Controllers
The evolution of the "smart" irrigation controller has ushered in a new era of technology that promises to "take" the homeowner out of the irrigation scheduling equation. The premise of the "smart" controller is to continually monitor changing plant/water demand and apply water when it is required. "Smart" controllers must also recognize rainfall in the irrigation schedule. Further, these controllers are designed to minimize runoff and deep percolation.

A testing protocol was developed by the Irrigation Association (IA) to evaluate the performance of "smart" controllers. All versions are available at the IA website www.irrigation.org. The protocol is in its 6th draft and is currently being used to test and evaluate controllers by The Center for Irrigation Technology at California State University, Fresno.

The protocol defines a procedure for characterizing the efficacy of irrigation system controllers that utilize climatological, soil, or plant data as a basis for scheduling irrigation events. Controllers may also use on-site temperature or rainfall sensors. This evaluation concept requires the use of accepted formulas for calculating crop evapotranspiration (ETc). Commercial examples of this type of controller include the following:

- Controllers that store historical ETc data characteristics
- Controllers that utilize an on-site sensor as the basis for calculating real time ETc

- Controllers that utilize a central weather station as a basis for ETc calculations and transmit the data to individual home owners from remote sites
- Controllers that utilize rainfall and temperature sensors
- Control technology that is added on to existing time-based controllers

The art and science of applying irrigation water to turf and landscape areas is a practice developed over time. While general procedures based in science give an appropriate framework for determining irrigation amounts and frequency, the "fine tuning" of the irrigation schedule is often developed as a site-specific practice.

The protocol was developed to mimic typical and problem irrigation landscapes found anywhere in North America. It is recognized that the *virtual* yard utilized in the IA's testing protocol cannot represent every conceivable irrigated landscape. However, it is also recognized that many irrigated landscape areas can be categorized as "typical" and that others can be identified as "problematic."

While the landscapes and irrigation systems used in the evaluation are *virtual*, the weather conditions used to monitor the controller's ability to track changes in the plant water demand are real-time. Specific weather stations are identified to provide the baseline demand for the irrigated landscape. The controller must take this information into account, along with other onsite information, to maximize the efficiency of applied water.

The idea of evaluating six irrigated zones which represent both the typical and problematic landscapes attempts to evaluate the controller's ability to adapt to a variety of conditions found in the field. The evaluation also emphasizes those conditions that use the most water (turf grass) as well as those conditions that cause irrigation water to run off (tight soil/high application rate).

The *virtual* landscape uses a mix of turf grasses, ground cover, shrubs and trees, combined with four types of irrigation methods, to represent a variety of conditions found in the field. Additionally, six types of soils and slopes are also presented in the evaluation. The irrigated zones are limited by root zone depth, percentage of full sun, and estimated irrigation application efficiency.

It is noted that the exact landscaped area and conditions used in the IA protocol may not exist anywhere in the world. It is also recognized that elements of this landscape are likely to exist everywhere landscapes are irrigated. The protocol was designed to represent a set of field conditions that controllers should be expected to effectively manage.

The IA protocol does not have a pass/fail rating. The procedure is designed to evaluate the controller's performance against an established "ideal" standard. The protocol utilizes the Environmental and Water Resource Institute (EWRI) of the American Society of Civil Engineers (ASCE) study on the standardization of reference evapotranspiration (ETo) formulas for the baseline. Other widely recognized standards are also cited in the protocol.

Efforts are underway to identify the appropriate agency (state or Federal) that can set the expected performance bar for controllers. Once a pass/fail limit is set, incentives designed to accelerate the adoption of "smart" controllers can be implemented by water purveyors.

The promise of significant water savings offered by the widespread adoption of "smart" controllers has led to the recommendation that beginning in 2010 all new irrigation controllers sold in California will have to meet the requirements of the IA Controller Testing protocol. This recommendation comes from a State Task Force created by Assembly Bill 2717 which was charged with developing new landscape irrigation guidelines and policy recommendations for the legislature. It was also recognized that a minimum performance level for "smart" controllers must be set, and the expectation is that this would be established by the California Department of Water Resources.

Soil Moisture Sensors

Soil moisture sensors are another promising technology for irrigation scheduling. Sensors can provide closed-loop feedback to time-based system controllers. This allows controllers to recognize soil moisture levels and terminate irrigation events when soil moisture reaches predetermined levels. More sophisticated controllers can have the ability to interpret soil moisture readings to determine frequency and duration of irrigation events.

The Irrigation Association has developed a Soil Moisture Sensor protocol to evaluate sensors under laboratory conditions. This extensive evaluation looks at the sensor's responses under varying levels of moisture, soil type, and salinity. The test is designed to expose the sensor to a wide range of conditions that exist in the field.

There are a number of fundamental principles used in the design of soil moisture sensors. These principles include electrical conductivity (EC), time domain reflectometry (TDR), and heat dissipation, to name just a few. Each of these principles has inherent strengths and limitations. Calibration requirements, repeatability, and accuracy over the range of test conditions represent some areas of potential variability. The cost of soil moisture sensors, while not directly identified in the testing protocol, will also influence the rate of adoption.

Future of SWAT™

A committee on the future of SWAT™ has been established through the Irrigation Association. Members of the committee represent water purveyors, industry, and government agencies. The committee's role is to expand the list of product categories that can demonstrate high water use efficiency. Currently a list of five product categories has been identified. Beyond the initial *scheduling technologies (e.g. controllers, sensors)*, four additional product categories have been identified which include:

- ✓ Overhead irrigation technologies (e.g. sprinklers, sprayers, nozzles)
- ✓ Low volume irrigation technologies (e.g. emitters, distribution systems)
- ✓ Hydraulic management devices (e.g. pressure management, check valves)
- ✓ Malfunction abatement technologies (e.g. high-flow shut offs, self-cleaning filters)

Nearly every irrigation product can be assigned to one of these five categories. It has been proposed that the categories will be ranked high to low, with the number one ranking having the greatest water-efficiency potential. Each succeeding lower ranking will signify a diminished potential in water-efficiency savings.

Initial funding has been identified for the review of the proposed product categories. After completion of the review, protocols will be developed for each category, starting with those products found in the number one category. The process will continue until protocols have been developed for all water-efficient products.

It is anticipated that eventually the SWAT™ process will include approved design, installation, and maintenance requirements. The long term goal is that a "SWAT™ designated irrigation system" will include a SWAT™ approved design, use SWAT™ products, and be installed and maintained according to SWAT™ guidelines. The end result will be an irrigation system that achieves the highest possible water use efficiency under commercial conditions. This goal fully recognizes the importance of water as a finite resource.

Water Efficient Sprinkler Irrigation Systems

The best way to understand an irrigation system is to acknowledge it is a "system". Webster's dictionary defines "system" as *a regularly interacting or interdependent group of items forming a unified body.* The key list of items used in landscape irrigation includes the design (engineering); water management (when and how much water to apply); equipment (pipes, valves, emission devices, controllers, etc.); installation; and maintenance. If done wrong, any one of these items or activities will have a negative impact on water use efficiency.

It is the sum of all the parts going into an irrigation system that gives us application uniformity and management. When purchasing a new irrigation system you should be able to specify both the level of uniformity and management. Just like you would reject buying a car that reported to achieve 15 km/liter (35 mpg), but actually delivered much less, we should define the level of irrigation uniformity at the contract stage and then prove it at system start-up.

The basic concept behind irrigation uniformity is to apply the water as evenly as possible. Most irrigation scheduling is driven by the dry spots, or the areas that receive the least amount of water. However, applying more water to the "dry spots" over irrigates the rest of the plant material. Reducing the difference between the minimum and maximum wetted area is the goal of highly uniform water application.

The uniformity of irrigation systems can be easily modeled to determine expected uniformity based on site and design considerations. The basis for modeling the irrigation uniformity of an irrigation system is derived from a single leg sprinkler profile test. These tests can be performed either in an indoor laboratory or outside in the field.

Catchcans are placed at equal distances, starting from the nearest sprinkler head and extending beyond the wetted radius of the sprinkler. Only one sprinkler is operated during the test period.

The test duration is established by the application rate of the sprinkler, with minimum catchcan readings of at least 250/mm per hour (10/inch per hour) suggested.

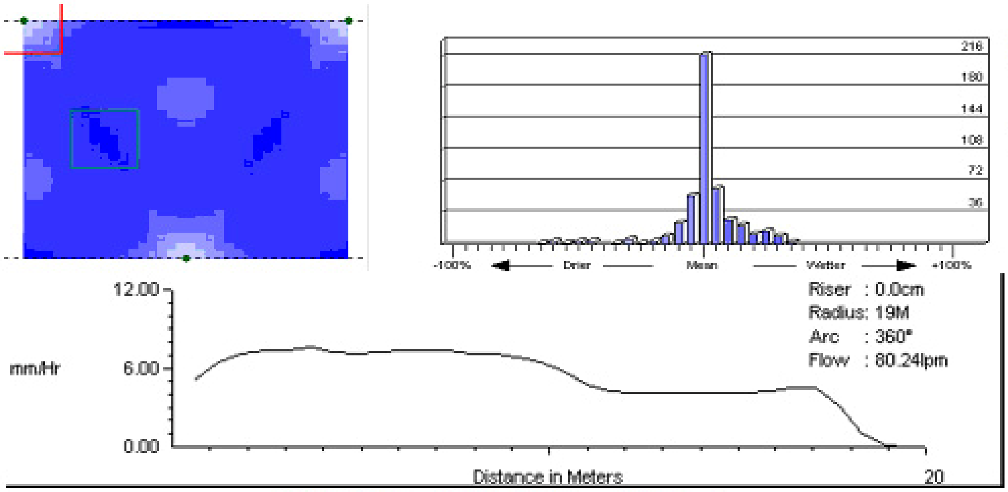
The variety of possible combinations include sprinkler model, nozzle size, operating pressure(s), and spacing distance and configuration (e.g. square vs. triangle). The water application uniformity as measured in the overlap area can be statistically calculated in numerous ways. The Coefficient of Uniformity (CU) as defined by J.E. Christiansen is historically one of the most referenced measures of uniformity. There are several weaknesses to this metric, such as treating over and under irrigation the same. Most irrigation management is driven by the dry spots.

Distribution Uniformity (DU), based on the low quarter, is a method commonly used in the field audit process. It is a measure of the low quarter or driest 25% of the coverage area compared as a ratio to the average. While DU focuses on the under-irrigated area by providing the average precipitation, we have no reference to the size and shape of the dry area(s).

A third measure of sprinkler irrigation uniformity is using the Scheduling Coefficient or SC. The SC uses a ratio of the average application rate compared to the average found in the driest continuous application area (usually specified as 1, 5, or 10% of the pattern area). This ratio, which must be one or greater, is used to estimate how long the irrigation system must run to apply the minimum needed water to the driest area. The larger the SC number, the longer the system must operate to keep the dry spots green. An irrigation system with an SC of 1.5 would have to run 50% longer than a perfectly uniform system with an SC of 1.0 to apply equal amounts of water to the driest part of the coverage area.

In Example 1. below, the data presented represents an existing sprinkler/spacing combination found in the field. Note that the densogram (top left) shows the three sprinkler heads contributing to the repeating coverage area. The red box at the top left of the densogram indicates the driest, continuous 5% of the coverage area. Conversely, the green box located near the center shows the wettest continuous 5% area.

Example 1 - Existing Sprinkler Coverage

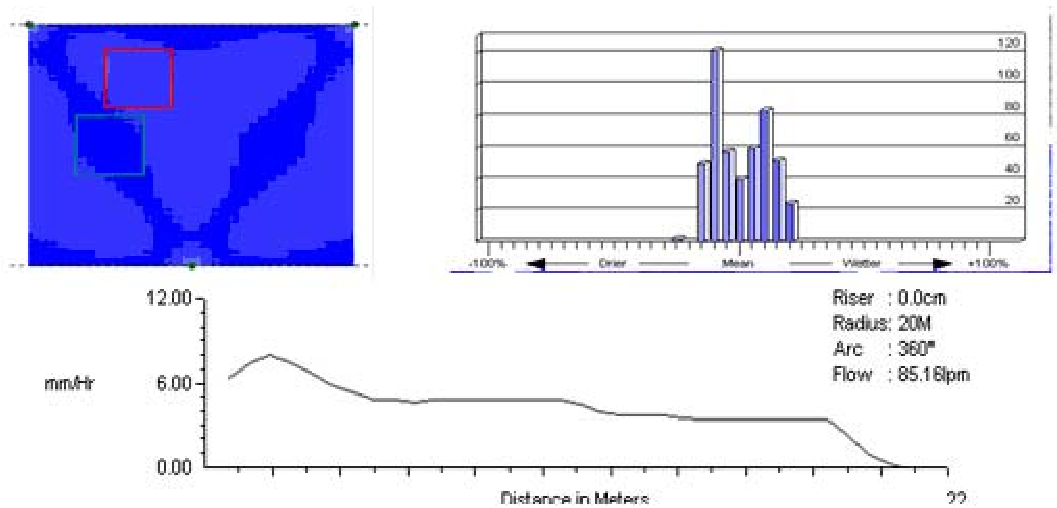


CU 88% - DU 83% - SC 1.8

The histogram (top right) shows the dispersion of catchcan readings from the mean. While the majority of catchcan measurements are found at the mean, a significant number received up to 50% less water than the mean value. This variance makes the management of the irrigation system more difficult, particularly in the dry areas around the sprinkler head.

The bottom graph in Example 1. shows the total distance of throw and water application at various distances from the sprinkler head. The geometry of this profile is rather “flat” which produces a Uniformity Coefficient 88%; a Distribution Uniformity using the Low Quarter of 83%; and a Scheduling Coefficient of 1.8. These existing measures of uniformity are compared to proposed changes of the nozzle configuration as shown in Example 2.

Example 2 - Improved Sprinkler Coverage

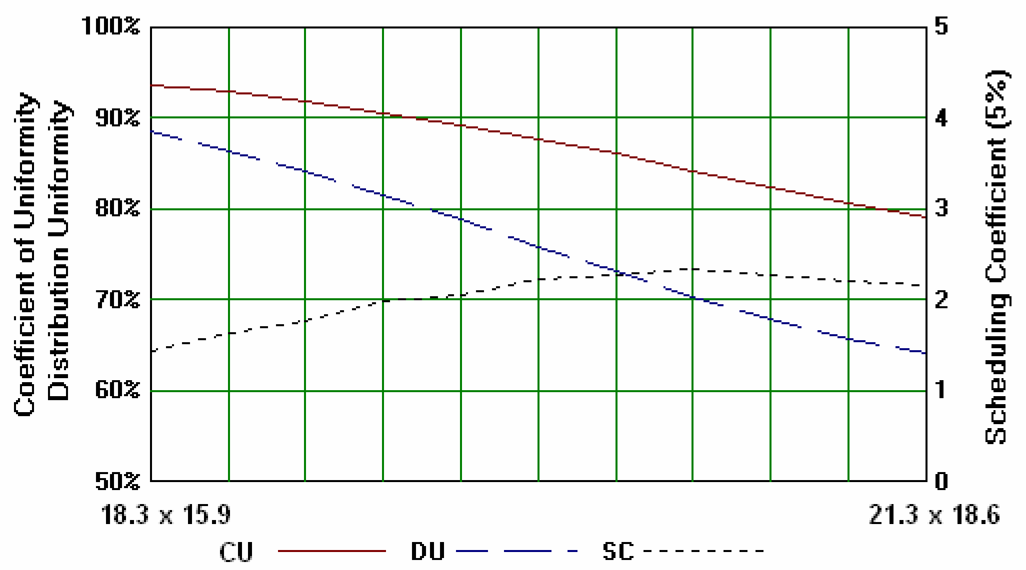


CU 92% - DU 87% - SC 1.1

The sprinkler parameters used in Example 2. are identical to Example 1. except for the nozzle geometry used in the sprinkler. The standard, straight bore nozzle used in Example 1. is dependent on water pressure to provide the break-up necessary to distribute the water along the sprinkler radius. The nozzle used in Example 2. utilizes both water pressure and nozzle geometry to achieve higher application uniformity based on an improved sprinkler profile. The result is a profile which can be described as “wedge” shaped.

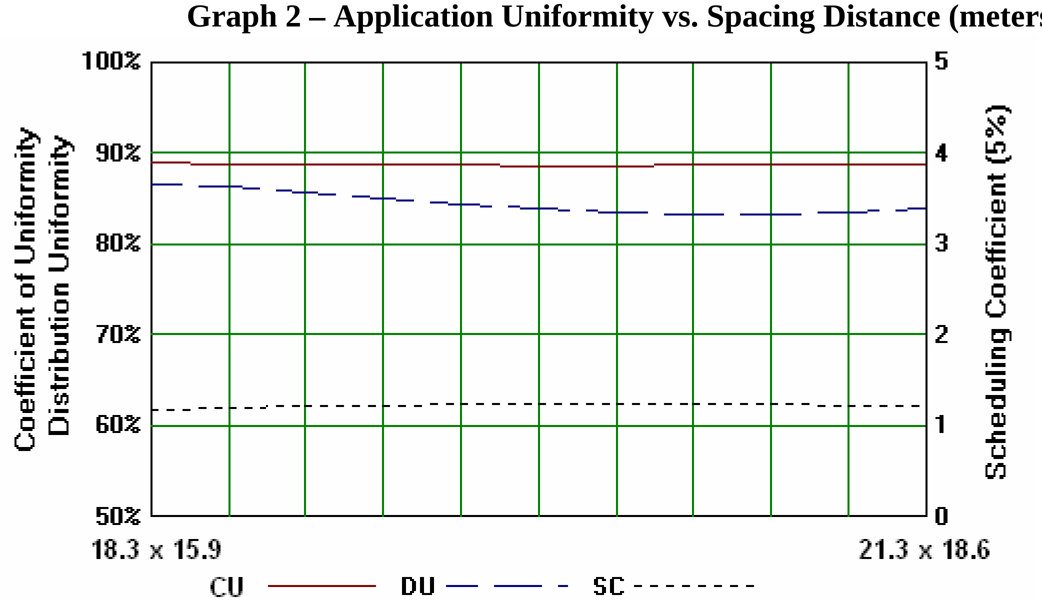
Irrigation or water application uniformity is a function of the sprinkler profile and distance in feet of the sprinkler spacing in the field. Graph 1. shown below depicts changes in distribution uniformity as a function of field spacing. The far left column characterizes various measures of uniformity (93% CU, 88% DU, and 1.4 SC) at a 18.3 m by 15.9 m (60 ft by 52 ft) triangular spacing. Located at the far right column is the same sprinkler spaced at a 21.3 m by 18.6 m (70 ft by 61 ft) triangular spacing. The uniformity is reduced to 79% CU, 64% DU, and 2.2 SC. The degradation of uniformity as impacted by an increased distance between the sprinkler heads represents a 24% reduction in DU. The other two uniformity measurements reflect similar changes. Other data points and spacings are represented in the graph between these two extremes.

Graph 1 – Application Uniformity vs. Spacing Distance (meters)



A different sprinkler/nozzle combination, and thus a different profile produces a substantially different result in Graph 2. The far left column characterizes various measures of uniformity (89% CU, 86% DU, and 1.2 SC) at a 18.3 m by 15.9 m (60 ft by 52 ft) triangular spacing. Located at the far right column is the same sprinkler spaced at a 21.3 m by 18.6 m (70 ft by 61 ft) triangular spacing. A high level of uniformity is maintained at this significantly greater spacing of 88% CU, 84% DU, and 1.3 SC. In this case, the uniformity degradation is only reduced by 4% as measured as DU. Again the other two measures of uniformity are only slightly affected by the change in sprinkler spacing.

Graph 2 – Application Uniformity vs. Spacing Distance (meters)



The message in comparing these two graphs is that not all sprinkler profiles are created equal. Some are much more forgiving over a greater distance as found in the field. It is not uncommon for the field spacing of sprinklers to vary widely when mature trees or hardscape interfere with sprinkler placement. So knowing how a sprinkler profile reacts to a range of potential field spacings can help select products that will perform the best. We can summarize that the sprinkler profile shown in Graph 1. is not as forgiving as the sprinkler profile shown in Graph 2. Given that all other considerations are equal, selecting the sprinkler profile as shown in Graph 2. would be the best choice of products and performance shown.

Summary

There are two key elements to high water use efficiency in irrigation. One is to apply the proper amount of water when the crop needs the water. Attention must also be given to how the water is applied to avoid run-off. This may include cycling of the valves to avoid the surface movement of applied water.

The second key to high water use efficiency is to apply water as uniform as possible. While current technology does not allow for 100% uniformity of applied water, improved sprinkler designs and drip/micro have improve irrigation uniformity significantly in recent years when properly designed and installed.

We now have the tools to model sprinkler application uniformity before the system is purchased and installed in the ground. Given this, it is reasonable to specify irrigation application uniformity in a contract before purchasing an irrigation system. Auditing can be used to verify the system performance after installation.

The combination of Smart Water Application Technologies™ (primarily “smart” controllers) with highly uniform sprinkler and/or drip irrigation systems will produce high water use efficiency (leading to significant water savings over conventional practices). Optimizing only one of these options will still lead to the potential of significant over irrigation. High water use efficiency can be best summarized by following the two basic tenets of:

a) Only apply water in the amounts and times the plants require , and,
b) Apply the water as uniformly as possible.

Literature Cited

Barrett, J., B. Vinchesi, R. Dobson, P. Roche and D. Zoldoske. 2003. *Golf Course Irrigation: Environmental Design and Management Practices.* John Wiley & Sons, Inc., New Jersey. 452 pp.

Oliphant, J.C. 1989. Modeling Sprinkler Coverage with the SPACE Program. *Center for Irrigation Technology May Irrigation Notes CATI Publication No. 890802*. 4 pp.

Solomon, K.H. 1989. A New Way to View Sprinkler Patterns. *Center for Irrigation Technology August Irrigation Notes CATI Publication No. 880802*. 4 pp.

Zoldoske, D.F., K.H. Solomon and E.M. Norum. 1994. Uniformity Measurements for Turfgrass: What’s Best. *Center for Irrigation Technology November Irrigation Notes.* 6 pp.

Soil Moisture Monitoring Equipment – What it Can and Cannot Do

Keith Backman
Dellavalle Laboratory Inc.
MS Pomologist, Certified Professional Horticulturalist, Certified Crop Advisor
422 N. Douty, Hanford CA 93230
Phone (559) 584-8322, FAX (559) 584-0523, kbackman@dellavallelab.com

Monitoring Equipment

Water monitoring instruments can provide accurate information if they are calibrated properly and positioned to answer the questions that you would like answered. Depth and width of the root zone moisture is key to evaluating the crops moisture status. Knowing the amount of available water in a large volume of soil under a tree is much more valuable than knowing the moisture content of a small sensor area. Any equipment placed arbitrarily, will give you arbitrary information.

I prefer the Neutron Probe to most other water monitoring devices. The advantage is its relatively large detection area. It senses an area almost as big as a volleyball. Irrigation problems often begin when the amount of water applied is 10% off. For example, if 10% less water is consumed than is applied, the wetted front of moisture will expand slightly at each event. With small area monitoring devices, such as a gypsum block or tensiometer, no monitoring data will change until the slowly increasing water front makes it to the next depth. The neutron probe will immediately note the increasing depth of the moisture advancing through its large sphere of detection. The neutron probe is also not effected buy salinity changes that can be caused by fertilizer addition, soil additives, and water source changes.

Neutron probes need to be carried to each site and therefore not compatible with the trend to real-time readings. Care needs to be taken with instant information. Many of my most difficult soil problems involve “slow water penetration”. In this situation water applied Tuesday finally arrives at its full depth in the soil Thursday or Friday. Reacting in an immediate panic, by doubling an irrigation, therefore demanding that the water immediately arrive at 3 feet can be disastrous. Think about it, if you enter a field carrying a soil probe or shovel a few hours following an irrigation event, don’t you expect muck at the surface and dry soil below?

Monitoring Data

Crops vary widely regarding how their water usage rates fluctuate during the season. One tree variety will use 20 or 30% more water than a seemingly identical variety. Some crops reduce their water consumption as harvest approaches while others do not change or begin to use water faster. In permanent crops the root stock determines where the tree will search for its water based on genetics, water availability, and soil characteristics. Many soils change your irrigation frequency requirements by changing water infiltration characteristics as the season progresses or as the water source changes.

There are many factors that can cause minor changes in instrument readings that are important for the decision maker to recognize. Is a sudden change in your soil water content due to the crop changing, the soil changing, the infiltration changing, your irrigator changing techniques, the weather changing, the crop getting sick or frisky? Or, is the instrument changing, or placed in the wrong spot, or subject to a soil amendment placed nearby?

Also remember that all components of the decision represent the area below the surface of the soil, where you cannot see. Generally if you wait to see the above ground portion of your crop (i.e. the top of your tree) show reactions, it is too late to order water and formulate an irrigation plan. It becomes time to minimize your losses.

Monitoring devices all have a flaw when it comes to scheduling irrigations. They can't do it! That is to say, they are incapable of making all of your irrigation decisions. No more than a hand-lens would make you an entomologist or a stethoscope makes you a doctor; an irrigation-monitoring device simply provides information for you to make a decision. I frequently hear "I bought this irrigation monitoring gadget at the farm show, and now I can accurately irrigate my crop". That reminds me of another phrase, "Ain't gonna happen!".

Cost Effective Soil Water Management Instruments

Doug Staley
National Sales Manager
Irrometer Company
P.O. Box 2424 Riverside, California, 92516
951/689-1701
www.irrometer.com

Irrometer Company
The Irrometer Company began in Riverside California in 1951 with the manufacture of a tensiometer, and after a few bumps and burps, an instrument that performed accurately and reliably was offered to the Ag Industry. From those early days in our existence we've developed and continued to improve on other irrigation scheduling and management tools which are simple to use, inexpensive to buy, and provide useful information used by the grower to increase his yields, and save water and energy.

The Irrometer
Our tensiometer, which we prefer to call an Irrometer, is the simple mechanical instrument for monitoring available soil moisture in a plant's active root zone. Rather than measuring the percentage of moisture in the soil at a monitoring station, the Irrometer is actually providing a reading of how hard the plant is working to obtain the available moisture. The instrument is made in various lengths, allowing the grower to see the dynamics of moisture and tension activity at several depths in a root profile. There are three different Irrometer configurations used in Agriculture. The differences in the full sized models are recognized by the tip styles and colors on the full sized models, and then there's the LT "mini", a miniature Irrometer designed for nursery pots. The white tip is the standard and original, is effective in soils that vary from clay to sandy loam, and the vacuum gauge on this standard model reads from 0 to 100 centibars. The blue tip provided on the Irrometer full size and "mini" LT models, is for use in coarse sandy soils and in non-soil planting mixes, and the gauge on these reads from 0 to 40 cb to give adequate response time in low tension soils.

Centibar readings are taken periodically by reading the vacuum gauge on each unit, which is then marked on a graph chart provided with the Irrometer service kit. When the reading/centibar marks of each instrument are connected, a linear trend is developed allowing the user to see the effect of each irrigation event, the results of a rain, and when two or more instrument depths per station are installed, an indication of water movement as it leaches downward or is used by the crop. The grower makes his decision to irrigate, based on seeing the dry, or the high side of his predetermined envelope, and knows when to shut down the pumps by seeing the lower wetted effect from his last irrigation duration.

The cost of an Irrometer varies by size, ranging from $70.00 to $111.00 each depending on the model and features. Whether the user buys one Irrometer, or one hundred in various lengths, he'll also need one $46.75 Service Kit which includes a pump to charge the units, a 2 year supply of monthly chart forms, a bottle of Irrometer coloring fluid, and the instructions for installing, servicing, record keeping, and using the instruments to make intelligent application decisions.

Whether a grower is using Irrometers, or the Watermark sensors, the Irrometer Company recommends locating a single, multi-depth sensor station per 20 acres in most crops. This can vary though, depending on terrain and soil differences within a field. To give you a rough idea of cost per acre using Irrometers, we'll look at an 80 acre established vineyard in sandy loam soil, and generally flat terrain. We'd initially recommend instruments that would read at 3 different depths, probably at 12" deep, 24" and 48 A grower who takes reasonable care of his instruments can expect a very minimum life of 10 years, and I've been in the field with growers who have had the instruments on their ranch for over 20 years.

The SSAT Tube

The SSAT name stands for the description – Soil Solution Access Tube. The SSAT tube looks just like an Irrometer minus the gauge and reservoir, and is actually a Lysimeter, used for extracting soil water samples from plant root zones. It's used for checking nitrate levels, salinity, EC or other chemical elements commonly associated with soil water management in irrigation. SSAT tubes cost from $26.25 for a 6" unit up to $37.25 for a 6' long instrument. SSAT tubes are to be installed semi permanently at various sites in a field for monitoring trouble spots throughout the season, though I know most users pull them, clean them up and reinstall at other sites after a couple of weeks.

The Watermark Sensor

Often called gypsum blocks, the Watermark sensors are an electronic, solid-state version of the ceramic Irrometer tip, and are properly described as Granular Matrix Sensors. Read with a digital meter, or a data logger, Watermark sensors are also installed in the root zone of the crop, and when an electrical pulse is sent through the wiring it crosses through the gypsum buffered matrix between two contacts, and the return signal is calibrated to centibars of suction. A gypsum wafer is embedded in the matrix, and unlike the old gypsum blocks, lasts for a minimum of 7 years or longer. A Watermark sensor has a wider measurement range than the Irrometer, in that it provides readings from 0 to 200 centibars. Inherent advantages of the Watermark are that it requires no maintenance through the season, is not affected by freezing temperatures, and is very affordable at $30.50 per sensor. Like the Irrometers, Watermark sensors are installed at measured depths at each reading station, and water use and movement through the root zone are recorded and charted to aid with irrigation scheduling. Literally hundreds of thousands of these sensors are working in fields around the globe. Watermark sensors should perform a minimum of 7 years with no maintenance.

The Watermark Digital Meter

The original instrument for reading Watermark sensors and about the size of a handheld voltmeter, the Watermark Digital Meter is one of the 'brains' of the Watermark line, in that it converts the electrical resistance reading of the sensor to centibars (or suction). It is a portable unit, and is sold with a protective carrying case, the connecting pigtail, a book of blank graphs, and the directions for operation. It lists for $280.00, and only one meter is used to read innumerable sensors in the field. It is set at a default soil temp of 75 F, but can be reset to reflect actual soil temperatures when especially precise centibar readings are needed. The meter is powered by a 9 volt battery, which normally lasts a year or longer.

The Watermark Data Loggers
As of November 2006, there are now three operating versions of the Watermark Data logger. The original model reads the input from as many as eight different sensors, and each of the eight connections can be programmed to read a temperature sensor, a moisture sensor, a switch, or a signal from a RSU model Irrometer. The logger will automatically read each sensor as often as once every minute, or through varying intervals to as seldom as once daily. Each Watermark data logger is sold with operating directions, software on a CD for loading into your computer, a connecting cable for downloading data into your computer, one temperature sensor and seven moisture sensors. Programming is basic and simple, and any grower who can use his Email program can be taught to set up the logger in about 15 minutes. This logger is downloaded at the installation site with either a laptop or a PDA. Graphing is automatic with the provided software, but raw data is available in comma separated value format for use with many spreadsheet programs, such as Microsoft Excel. Software is available in seven languages.

In 2004, we added the feature of radio telemetry. The standard logger is mounted on a post or mast with the added equipment of a solar panel, a 12-volt battery, and a radio transmitter. These allow the grower to, with the use of a small base radio, connect and download the collected data from the seat of his truck, or even his office desk if the office is within a 'line of sight' 10-mile radius

New in November 2006, is the wireless sensor logger. Hearing concerns from our customers who were suffering from "copper shock", we've developed a limited range field radio that's installed at each sensor station in the field. Capable of reading four sensors each which are installed directly below the field radio, the unit is mounted on a short field post or 2" PVC pipe, and transmits a 1,500' 'line of sight' signal back to a new model Wireless Monitor. This Wireless Monitor is capable of receiving, downloading and saving data from as many as 16 field radios, which, when the math is done, can read up to 64 individual sensors. This unit also can be downloaded onto a PDA or laptop in the field, or when the bigger battery and solar panel are added, will transmit to the same base radio as in the original model. A great deal of interest in this unit has been received industry wide, with particular attention from wheel line and pivot manufacturers and users, though it is not at all limited to those. This new Wireless Logger was introduced in November at the International Irrigation Show in San Antonio

For those of you in California, Oregon, Nevada and Arizona, Irrometer Company sales guys are seldom more than a couple of days away, and are anxious to advise on installing the first system, as well as spend time with the grower both in programming the loggers, and in making suggestions on how to schedule irrigation events based on data collected.

New Ideas for Fertigation

Jerome Pier, Ph.D., Central Valley Division Agronomist
Western Farm Service, 509 W. Weber Ave, Suite 201, Stockton, CA 95203
jpier@agriumretail.com www.westernfarmservice.com

Application of liquid fertilizers through irrigation water, also known as fertigation, is an efficient and agronomically sound method of providing soluble plant nutrients directly to the active plant root zone. The increasing acres of micro-irrigated crops provides an excellent opportunity to explore new methods of providing complete and balanced plant nutrient programs that have the potential to improve plant health and increase yields.

Burt *et al*. in 1995 interviewed and reported a sample of fertigation practices based on grower interviews in their book "Fertigation". Growers mainly applied commodity materials such as urea ammonium nitrate, ammonium nitrate solution, calcium ammonium nitrate, and potassium thiosulfate and common liquid blends such as 8-8-8, 10-0-10 and 4-10-10. Growers also used N-pHURIC® or urea-sulfuric acid for water pH modification and line cleaning. Many growers once used suspension machines to apply fine grade gypsum through drip systems. The difficulties of handling the large quantities of gypsum resulted in many solution machines now sitting. Until recently, little has changed in terms of products used in fertigation.

More growers are taking novel approaches to fertigation. More growers are applying soluble calcium materials such as calcium chloride, calcium nitrate solution and calcium thiosulfate to aid in water penetration, provide nutritional and exchangeable calcium that was leached from the soil by application of low salt snow melt irrigation water. Other growers are using custom liquid blended fertilizer formulations based on soil and tissue analyses. More liquid blends incorporate materials other than urea ammonium nitrate, ammonium polyphosphate and muriate of potash. A need for lower salt index fertilizers has led to use of potassium nitrate and potassium thiosulfate. Growers are applying humic and organic acids as well as microorganism preparations through drip systems with good results. Growers are using more acid blends to provide soluble plant nutrients, clean drip lines and modify high soil pH.

The cutting edge of fertigation is application of complete, balanced nutrient solutions to supply all plant essential nutrients. More growers understand that application of nitrogen alone weakens plants leading to diseases and inferior quality crops. The increased yields and quality necessary for profitable farming has revealed growth limiting factors that can be overcome by applying complete nutrient solutions that match crop nutrient uptake requirements for distinct growth and development stages.

The difficulty in applying complete nutrient solutions lies in the incompatibility of several important plant nutrients. Calcium, magnesium and divalent micronutrient cations (iron, zinc, manganese and copper) precipitate phosphate and plug drip emitters. Chelated micronutrients can prevent some precipitation. However, the relatively large amounts of calcium and magnesium necessary for optimum plant growth prevent formulating single tank complete liquid fertilizer solutions.
There are two methods of applying complete nutrient solutions: sequential application and

continuous, concurrent application. Both methods require two or more tanks for incompatible, concentrated liquid blends and multiple port injection pumps. The most common setup has one tank, commonly referred to as the 'A' tank, containing a blend of nitrogen, phosphorous, potassium, sulfur, boron and molybdenum. The 'B' tank contains calcium, magnesium and chelated metal micronutrients. Sequential applications are accomplished by injecting from the A tank first, followed by a flushing cycle to rinse the fertilizer from the lines and finishing with injecting from the B tank. Sequential applications can apply higher rates of fertilizer blends formulated with standard materials. Sequential applications require longer irrigation set times to allow for complete flushing between applications of incompatible blends. Continuous, concurrent application adopts the technique used in one-pass hydroponic systems whereby incompatible materials will not precipitate if applied at low concentrations. Continuous application allows for shorter set times but not as much fertilizer can be applied and the materials used should be low in non-nutrient salts. A flush cycle to remove all fertilizer from the irrigation system after injection is required for both methods. Advances in drip emitters that are less susceptible to plugging at low flow rates has created an opportunity for more growers to try continuous, concurrent applications of complete nutrient solutions.

Drip irrigation applies water and nutrients to a small volume of soil. Frequent drip irrigation creates a moist, aerated soil environment ideal for root growth. Fertigation supplies concentrated plant nutrients almost directly to plant roots minimizing interference from soils that would otherwise make nutrients unavailable. Long established critical values for plant nutrients in tissue samples become less reliable under continuous fertigation as plant growth and development outpaces threshold levels that were developed from single nutrient yield studies under conventional management systems. For this reason it is more reliable to take a programmed approach to meeting plant nutrient uptake by growth stage and use tissue sampling or sap analysis to make periodic checks on how well the program is meeting plant nutrient demand. For crops where nutrient uptake curves have been determined under drip irrigation, one would divide the growing season into developmental stages (early vegetative, early reproductive, fruit development and ripening, as an example) and change the nutrient ratios of the fertilizer blends to match the needs of the crop for each stage. Whole plant analysis for all nutrients at each developmental stage should be performed if no uptake curves are available. Whole plant analysis is not practical for woody perennial crops. Only a few intensive uptake studies have been performed (almond, pistachio and avocado). Instead, one could estimate woody crop nutrient demand from sub-samples of various plant parts throughout the growing season combined with an estimate of plant biomass.

Fertigation provides an opportunity to approach theoretical maximum yield potentials. Growers are beginning to take advantage of the benefits of fertigation by applying more sophisticated programs and non-standard fertilizer blends that improve nutrient uptake efficiency and plant health. The rewards are high quality plant products that command a premium price in a competitive marketplace.

Maintaining and Optimizing Drip Systems

Larry Schwankl
Dept. of LAWR, UC Kearney Ag Center, 9240 S. Riverbend Ave., Parlier, CA 93648
559-646-6569 schwankl@uckac.edu
Terry Prichard
Dept. of LAWR, 420 South Wilson Way, Stockton, CA 95205
(209) 468-9496 tlprichard@ucdavis.edu

Rachel Elkins
UC Cooperative Extension–Lake Co., 883 Lakeport Boulevard, Lakeport, CA 95453
(707) 263-6838 rbelkins@ucdavis.edu

John Edstrom
UC Cooperative Extension–Colusa Co., 100 Sunrise Boulevard, Suite E, Colusa, CA 95932
(530) 458-0570 jpedstrom@ucdavis.edu

Introduction

Maintenance and operation of drip irrigation systems is a wide-ranging topic and there are a number of texts and handbooks available on the subject (Burt and Styles, 1999; Lamm et al., 2007; Hanson et al., 1997; and Schwankl et al., 1998). The following is a discussion of selected topics on maintaining and managing drip irrigation systems.

Maintenance Issues in Drip Irrigation

Clogging of drip emitters is the major challenge for drip irrigation managers. The small emitter passageways can be partially or totally blocked by foreign particles such as sands, chemical precipitates, or biological growths such as algae or bacterial slimes. The additional hazards of root intrusion and soil injection are present when subsurface drip systems are used.

The topics of monitoring for emitter clogging problems, iron precipitate clogging, and root intrusion in subsurface drip irrigated tree crops will be discussed in greater detail.

Monitoring for Drip Emitter Clogging

Clogging problems often begin as partial clogging of some emitters and progressively get worse. If the drip system can be monitored so that clogging is detected early, steps can often be taken to solve the problem.

The most effective form of monitoring for emitter clogging is to regularly collect discharge from a sampling of drip emitters. For example, collect 30 seconds of discharge from 50 to 100, randomly selected, emitters in an orchard or vineyard and determine if there is clogging occurring in any of them. This is an easy recommendation to make but the reality is that most drip system managers will not do such an evaluation sampling on a regular basis.

An alternative drip clogging monitoring technique has been to install a flow meter at the head of the drip irrigation system which can be monitored to determine if the system flow rate is decreasing over time – an indication that clogging is occurring. It has been found that a single, large flow meter monitoring the entire drip system is usually not sensitive enough to detect the initial stages of drip emitter clogging.

The use of small flow meters, installed on a sampling of drip lateral lines, has proven to be an effective drip clogging monitoring tool. These meters have a 5/8" or 3/4" throat section, are made of brass or plastic, last for years, and are inexpensive – less that $100 each. They are easily installed at the head of a lateral using PVC and drip irrigation fittings. Reading the meters weekly and keeping track of the drip system operating times allows the detection of any changes in emitter flow rates. The information is also an excellent way of tracking the applied water for irrigation scheduling purposes.

Iron Precipitate Clogging

One of the most difficult chemical precipitate clogging problems is precipitation of iron. Iron precipitation is most commonly associated with groundwater. In its reduced form (ferrous iron) in the well, the iron stays in solution, but when the groundwater is pumped it comes in contact with the atmosphere, oxidizes, and forms an insoluble precipitate (ferric iron). This precipitation will occur at water pH of 4 or above so acidification of the irrigation water is not a practical mitigation solution.

Iron concentrations as low as 0.5 ppm have been reported to cause iron precipitate clogging problems, but levels of 1-2 ppm are more commonly associated with drip emitter clogging. If a reddish staining is evident on buildings, trees, and fences which have had the water sprayed on them during irrigation, it is likely that iron precipitate clogging may be a problem when drip irrigating.

The most common solution to iron precipitate clogging has been pumping the groundwater via an elevated outlet into a pond or reservoir. In this process, the dissolved iron contacts the atmosphere, is oxidized, and precipitates. Time is then required for the iron precipitates to settle prior to removing the water for irrigation. To improve oxidation and iron precipitation, chlorine, a more effective oxidizer than air, can be added to the water as it is pumped to the reservoir.

If a reservoir is not available for settling the precipitated iron, an alternative is to filter out the precipitated iron. A recommended system to do this consists of injecting chlorine into the water, mixing and oxidizing the iron in a centrifugal sand separator, followed by sand media filtration to remove the iron precipitates. Generally a lower flow rate per filter area (less than the standard 15-25 gpm/ft^2 recommendation) is recommended in order to provide adequate time for iron precipitation to occur and for the precipitates to be filtered out.

A relatively recent option for controlling iron precipitate clogging in drip emitters is the use of phosphonic acid or phosphonate materials which are injected continuously, usually at levels of 5 ppm or less. These materials are described as threshold inhibitors which keep the iron in solution and minimize precipitate clogging.

A multi-year evaluation of four phosphonate/phosphonic acid products used to treat two groundwaters with iron concentrations of 2 ppm and 18 ppm was done in Lake County, CA. At the 2 ppm iron level, the phosphonate/phosphonic acid products were very effective at eliminating iron precipitate clogging. At the 18 ppm, an extremely high iron content, there was still some emitter clogging at the tail end of the drip laterals, but the phosphonate/phosphonic acid materials minimized clogging problems. At the iron levels commonly encountered, the phosphonate/phosphonic acid materials appear to be effective and should be considered when choosing an iron clogging mitigation strategy.

Root Intrusion in Subsurface Drip Irrigation of Trees

Subsurface drip systems used in tree crops are almost always “hard” drip tubing with in-line emitters. These products are more expensive than the drip tape used in vegetables and row crops, but they are expected to last much longer. In addition to the clogging issues common to all drip emitters, subsurface applications also face root intrusion clogging. Tree roots will grow into the drip emitters and clog the emitter passageways.

In a long-term, Colusa County, CA study on microirrigation systems in almonds, it was found that roots had intruded and substantially clogged the emitters in “unprotected” subsurface drip lines after six years of use. Drip emitters impregnated with the herbicide trifluralin showed no evidence of root intrusion until year 15 of use.

Once the root intrusion problem was discovered, remediation treatments including high-concentration chlorine injection and acid injection to lower the water pH were done. They were not successful in solving the problem. The almond roots found in the emitters were quite woody and would be difficult to “dissolve” away. Additionally, since the emitters are clogged, it is hard to deliver the treated water to the clogging site. Finally, the only solution was to replace the subsurface drip lines.

It has been suggested that trifluralin be injected into subsurface drip systems to inhibit root intrusion. It is unclear whether this will work. Research in the greenhouse with horticultural plants has indicated that trifluralin injections are not effective in preventing root intrusion.

Work has also been done on using copper (copper sulfate) to inhibit root intrusion into drip emitters. Copper ties up quickly on soil particles so injecting it through the drip system forms a zone of high copper concentration around the emitter. This high copper concentration zone is inhospitable to root development. A multi-year test implementing this strategy on walnuts found that the copper did tie up on the soil in a zone surrounding the emitters. By sacrificing and analyzing various portions of the tree, no copper uptake was found in any portion of the tree. While no root intrusion was evident in the “copper protected” treatments, there was also minimal root intrusion in the “unprotected” treatment so no firm conclusions could be drawn on the effectiveness of the copper treatment.

Following a discussion regarding drip emitter clogging by tree root intrusion and the copper injection prevention approach, a paper-producing company in Northern California growing eucalyptus for pulp wood using subsurface drip irrigation began injecting copper to mitigate a serious root intrusion problem. They reported success in significantly reducing their root intrusion problems.

Managing Drip Irrigation Systems

Chemigation Uniformity

Injection of chemicals (fertilizers, pesticides, drip system maintenance products, etc.) through the drip irrigation system is common and chemigation is a major advantage of drip irrigation systems. Chemicals injected through the drip system should be applied as uniformly as irrigation water applications but this is not always the case. The timing of injections and post-injection irrigation is very important in attaining uniform chemical applications.

Studies in San Joaquin County, CA and Davis, CA investigated the affect of injection timing on chemical application uniformity. In six commercial orchards and vineyards, the travel times of chemicals moving through the drip irrigation systems was monitored (Table 1) using chlorine as an indicator and pool/spa test kits for detection. The time from start of injection until the chemical reached the most distant point in the drip system ranged from 30 to 75 minutes. Once injection stopped, it took a comparable, or longer, time for all chemicals to be discharged from the drip system.

In a companion study, a 500-foot drip line with 1 gph drippers every 5 feet was tested for chemical application uniformity by varying the injection times and post-injection clean water operation times (Table 2). The travel time for chemical through this drip line was 25 minutes. The best chemical application uniformity was achieved when injection and post-injection times were twice (50 minutes) the drip line travel time of 25 minutes. Very acceptable chemical application uniformity was achieved with injection and post-injection irrigation times equal to the drip line travel time (25 minutes).

Table 1. Water and chemical travel times through pipelines and drip lateral lines for selected drip-irrigated vineyards and orchards.

Site	**Mainlines and submain pipeline**		**Lateral line**		**Total travel time (min)**
	Travel time (min)	**Length (ft)**	**Travel time (min)**	**Length (ft)**	
1	22	1,000	10	175	32
2	30	1,500	10	340	40
3	65	5,000	10	340	75
4	15	1,400	23	630	38
5	8	700	23	625	31
6	17	820	28	600	45

Table 2. Chemigation uniformity in a drip later (500 feet long with 1-gph drip emitters installed at 5-foot intervals) for various injection times and post-injection clean water irrigations. The water and injected chemical travel time to reach the end of the drip lateral was 25 minutes.

Injection time (min)	**Post-injection irrigation time (min)**	**Relative uniformity (%)**
50	50	100
50	25	98
25	25	95
25	50	90
13	25	81
50	0	25
25	0	11
13	0	7

Two injection strategies to avoid are injection times shorter than the drip system travel time, and injections not followed by clean water irrigation. The worst of these is short injection periods with no clean water irrigation following the injection (Table 2).

Optimal chemigation management is achieved by determining the travel time in the drip system. This is a one-time test and can be done by using a tracer dye or most easily by injecting chlorine and tracing its movement through the drip system with a pool/spa test kit. Once the travel time is determined, injection periods should be equal to the travel time or longer. Injection should be followed by a clean water irrigation period equal to or longer than the travel time.

If there is no knowledge regarding the drip system chemical travel time, an injection period of at least 1 hour, followed by a clean water irrigation period of at least an hour will achieve acceptable chemigation uniformity in most tree and vine drip systems.

References

Burt, C. and S. Styles, 1999. Drip and Micro Irrigation for Trees, Vines, and Row Crops. Cal Poly, SLO ITRC.

Hanson, B., Schwankl, L., Grattan, S., and T. Prichard, 1997. Drip Irrigation for Row Crops. UC ANR Publication 3376.

Lamm, F.R., Ayars, J.E., and F.S. Nakayama, 2007. Microirrigation for Crop Production. Elsevier.

Schwankl, L., Hanson, B., and T. Prichard, 1998. Micro-irrigation of Trees and Vines. UC ANR Publication 3378.

Schwankl, L. and T. Prichard, 2001. Chemigation in Tree and Vine Microirrigation Systems. UC ANR Publication 21599.

Using Environmental Quality Incentive Program (EQIP) Funds to Improve Irrigation Systems and Management in California

Dan Johnson[1], Arturo Carvajal[2], Robert Fry[3]

Natural Resources Conservation Service (NRCS) has supported technical and financial incentive programs to improve on-farm irrigation water management (IWM) for decades. IWM is a key element in achieving broad goals for efficient, equitable, and environmentally responsible water use. Appropriate use of natural resources by all segments of society is needed to maintain our standard of living. In terms of water this means a) optimizing use so that supplies can better meet current and future needs, and b) protecting water sources from pollutants that limit water uses.

NRCS irrigation cost share programs in California

NRCS views farm water management and the EQIP cost share program as two elements for meeting these broad goals. With EQIP NRCS will cost share on both irrigation hardware improvements, such as drip irrigation systems, and water management practices, such as irrigation scheduling and soil moisture monitoring. At this time far more money is spent on irrigation hardware improvements. However, NRCS believes the key to good water management is good hardware and a high level of management, regardless of the system type. NRCS would like to increase the amount of cost share going to management practices. If industry becomes involved by assisting producers to meet our requirements this will happen more quickly. Industry can encourage clients to sign up for water management practices and prepare a plan for system operation and maintenance, including recordkeeping, scheduling, and monitoring. NRCS must receive a plan and evidence it is being applied in order to release cost share funds. There are opportunities for industry providers to become Technical Service Providers (TSP) and receive some compensation for preparing plans to be used in EQIP contracts.

NRCS/EQIP 2004 Summary of Irrigation Water Conservation Practices in California

Practice Standard	%	Installed Cost
IRRIGATION LAND LEVELING	2.3	$ 180,723
IRRIGATION SYSTEM, MICROIRRIGATION	34.4	$ 2,694,946
IRRIGATION SYSTEM, SPRINKLER	29.5	$ 2,306,693
IRRIGATION SYSTEM, SURFACE	1.9	$ 146,352
IRRIGATION SYSTEM, TAILWATER RECOVERY	1.4	$ 113,246
IRRIGATION WATER CONVEYANCE, Ditch/Canal Lining	2.6	$ 200,426
IRRIGATION WATER CONVEYANCE, Pipeline, Alum. Tube	1.6	$ 121,354
IRRIGATION WATER CONVEYANCE, Pipeline, High-Pressure	10.5	$ 822,575
IRRIGATION WATER CONVEYANCE, Pipeline, Low Pressure	11.2	$ 877,795
IRRIGATION WATER CONVEYANCE, Pipeline, Other Material	3.0	$ 237,760
IRRIGATION WATER MANAGEMENT	1.6	$ 126,640
Totals:	**100**	**$ 7,828,510**

Details of the EQIP program can be found at:
http://www.ca.nrcs.usda.gov/programs/eqip/2007/statepriorities2007.html
At that site, review the documents listed below. They describe EQIP programs focused on irrigation water management. It is very important to contact the local NRCS office since each county will have a unique program.

Fiscal Year 2007 NRCS Environmental Quality Incentives Program (EQIP)
Klamath Basin Ground and Surface Water Conservation Initiative (GSWC)

NRCS California Environmental Quality Incentives Program (EQIP)
Ground and Surface Water Conservation (GSWC) Initiative – Fiscal Year 2007

Environmental Quality Incentive Program (EQIP)
California NRCS Regular County Program – Fiscal Year 2007

Technical Standards for Irrigation Water Management in EQIP contracts

Producers requesting cost share for water management practices should refer to the document reproduced below. The links in the document provide references and tools to help prepare and implement a plan. These links are included with the distribution CD, and are available upon request.

TECHNICAL NOTES

U.S. Department of Agriculture — Natural Resources Conservation Service

TN – ENGINEERING – CA-16 — Davis, CA — March 2005

NRCS CALIFORNIA

Suggested Elements of a Field Office Irrigation Water Management EQIP Incentive Program

Purpose

To provide guidance to assist field staff and program applicants in the selection of appropriate actions needed to achieve requirements of the Irrigation Water Management Practice Standard (449) and to assign appropriate levels of incentive payments in program contracts.

Technology

An IWM Incentive Program will be successful when the producer takes actions to improve his/her water management. NRCS can assist the producer in determining what actions will be taken and is responsible for documenting that water management improvements are being made. There are a number of alternative producer actions that may be appropriate. Below is general guidance and one suggested combination of actions. Each field office will decide how to "package" this program for delivery to EQIP participants.

WATER MANAGEMENT PLAN

NRCS should work with the producer to develop an overall water management plan. The plan does not need to be complicated but should present results of evaluations, identify opportunities for improvement, and document producer decisions on short and long term strategies for making any needed irrigation system improvements as well as how irrigation scheduling decisions will be made. The plan should also include guidance on how to utilize soil moisture, crop stress devices, or other irrigation scheduling methods.

IWM INCENTIVE PROGRAM, SUGGESTED STRUCTURE

Incentive payments are available to encourage producers to implement Practice Standard 449, Irrigation Water Management (IWM). IWM is a key element of the Water Management Plan and is defined by actions taken to control the rate and timing of irrigation water application (irrigation scheduling) to minimize excessive runoff and deep percolation. It is recognized that it may be difficult to identify and implement all necessary actions at one time. Expensive hardware changes may be necessary and it takes time to learn new methods. Therefore, producers can be given the option to enter into contracts that last one to three years to apply progressive levels of management.

Level 1 actions, as described below, should be considered the minimum to meet the requirements of Practice Standard 449 in California. Level 2 actions and associated incentive payments may be appropriate when local irrigation related resource concerns warrant higher levels of water management. The Field Office may establish an approach that uses additional levels. The Field Office should set incentive rates that reflect the investments the producer will make such as the purchase of equipment, employee time, or securing professional services. It's important to note, however, that in EQIP contracts these "investments" can not be listed as separately funded components. The producer is not required to submit bills or invoices for any incentive practice paid by a flat rate reimbursement. Suggested incentive rates and actions corresponding to each level are described below.

NRCS ACTIONS

In addition to evaluating the producer's current irrigation scheduling practices, Field Office staff assistance may be needed to assist the producer in understanding and carrying out selected suggested actions.

PRODUCER ACTIONS

The producer must be interested in improving his or her IWM and have, or be willing to install, acceptable flow measuring devices. Defective or improperly installed devices will need to be repaired or re-installed correctly. See the National Engineering Handbook, Irrigation Guide section on Water Measurement for guidance on selecting, installing, and evaluating flow measuring devices.

Level 1: Suggested Incentive Rate of $20/acre

Producer Actions

- Work with NRCS to evaluate current irrigation scheduling practices. Use the attached **"Irrigation Scheduling Inventory and Simple Evaluation"** (inveval.doc) and the instructions (invevali.doc) or equivalent to perform the evaluation.
- Determine soil moisture depletion (SMD) just prior to each irrigation. Measure using soil (gypsum blocks, tensiometers, feel and appearance), plant (pressure chamber, infrared), or climate (CIMIS, cimis.pdf) based methods. If devices are used, follow manufacturer's recommendations as to the number required, installation procedures, where to locate them in the field, and how to utilize readings. See attached **"Estimating Soil Moisture by Feel and Appearance"** (esmbfa.pdf) for using the "feel" method as well as information on acquiring soil sampling equipment. Utilize attached **"Record of Irrigation Dates"** (rirrdate.doc) or equivalent to record data.
- Keep a record of irrigation dates and amounts applied to each field. Utilize attached **"Record of Irrigation Dates"** (rirrdate.doc)**,** Table 2 of **"Irrigation Scheduling Inventory and Simple Evaluation"** (inveval.doc) and the instructions (invevali.doc) or equivalent to record data.
- Utilize a climate based method to make ongoing comparisons of actual timing of irrigations with average year irrigation schedules. See attached guidance on how to use the "Wateright" program (wtright.doc) and a spreadsheet of its inputs (wtrighti.xls). Utilize attached **"Record of Irrigation Dates"** (rirrdate.doc) or equivalent to record data.
- Demonstrate, through reports or assembling the aforementioned records that these actions are being taken.

Level 2: Suggested Incentive Rate of $30/acre

Producer Actions

- Work with NRCS to evaluate current irrigation scheduling practices *(unless done previously)*. Use attached **"Irrigation Scheduling Inventory and Simple Evaluation"** (inveval.doc) and the instructions (invevali.doc) or equivalent to perform the evaluation.
- Install flow measuring devices/methods if suitable equipment is not currently in place.
- Monitor crop water use with a soil (gypsum blocks, tensiometers), plant (pressure chamber, infrared), or climate (CIMIS, cimis.pdf) based method. If devices are used, follow manufacturer's recommendations as to the number required, installation procedures, where to locate them in the field, and how to utilize readings. See attached **"Estimating Soil Moisture by Feel and Appearance"** (esmbfa.pdf) for using the "feel" method.
- Determine target irrigation applications considering rootzone depth, allowable plant stress, soil water holding capacity and system limitations. Data should be collected from the methods used

and displayed in a usable form. See attached spreadsheet for tracking soil moisture device data (Steve Orloff et al., nwgraph.xlt).

- Schedule irrigations based on monitoring results.
- Keep record of irrigation timing and amounts and corresponding plant/soil water requirements. See attached **"Record of Irrigation Times and Amounts"** (rtimamt.doc).
- Demonstrate through reports or assembling the aforementioned records that these actions are being taken.

IRRIGATION SYSTEM EVALUATIONS

The producer can use incentive payments to help cover the costs of irrigation system evaluations. Evaluation results provide the producer with vital information that can be used to stretch limited water supplies while maximizing crop production. In an evaluation, measurements and observations are made to quantify and track water application during an actual irrigation event. At the completion of an evaluation a report is produced describing system performance including how uniformly the water is being applied or infiltrates the soil, how much is being applied each irrigation, and what system improvements may be beneficial. Evaluation services may be available from local Irrigation Districts, private consultants, Resource Conservation Districts, or other agency-sponsored Mobile Labs.

The typical cost per evaluation is about $1,000 for pressurized irrigation systems and $1,500 for furrow or border irrigation systems. Level 1 and Level 2 incentive rates can be increased to reflect the typical cost of evaluations. The Field Office should concur with evaluation methods and the content of reports to the producer. The Cal Poly ITRC evaluation methods and available training are strongly encouraged.

1/ State Water Management Specialist, 2/ Water Management Engineer, 530-792-5627, 3/ State Conservation Agronomist All authors are located at NRCS State Office in Davis, Ca.

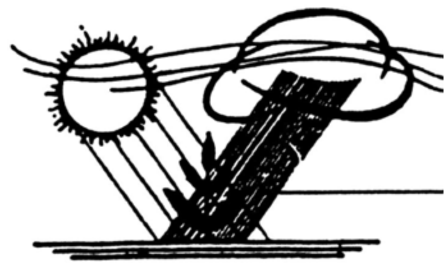
Session V

Transition/Diversification

Session Chairs:

David Woodruff, Woodruff Ag Consulting

Jeff Wong, Cal Poly, San Luis Obispo



2007 Farm Bill: Specialty Crops Policy Options and Consequences: A California Perspective

Jay E. Noel*
California Institute for the Study of Specialty Crops
California Polytechnic State University
San Luis Obispo, California

I. Introduction

The 2007 Farm Bill debate has started and the number of stakeholders, even by historical standards, is quite large. Among those who are actively engaged in the debate is the California specialty crop industry. The California specialty crop industry is comprised of producers and handlers of fruits, tree nuts, vegetables, melons, potatoes and nursery crops including floriculture.[2] This paper reports on the results of listening sessions and surveys that were undertaken to gain an understanding of the California specialty crop industry perspective regarding the importance of potential specialty crop farm policy options that could be included in the 2007 Farm Bill

Two types of listening sessions were conducted to gather information regarding the public policy issues that the California specialty crop industry considers important. First, a number of conversations were held with specialty crop producers and grower organizations. Second, a number of meetings were attended where specialty crop producers and representatives of agricultural organizations presented their views. The conversations and meetings provided valuable insight into the breath and range of policy issues that are considered important by California specialty crop producers.

In an attempt to gain a more representative sample of specialty crop industry participants thoughts relative to the importance of different farm policies, two targeted surveys were conducted.[3] The surveys were divided into the following sections: domestic policies, farm income safety net policies, research policies, environmental/conservation policies, trade policies, and the importance of federal farm policies to California producers. Fifty-two surveys were mailed to specialty crop organizations and seventeen were returned. The second survey was a web based survey of Western Growers Association (WGA) members. Over 1200 WGA members were notified by email requesting their participation in the survey; twenty-one completed responses were received.

The low response rates are not unusual for these types of survey and thus do not allow for any statistical conclusions. However, the anecdotal survey information in conjunction with information gained from the listening sessions allows for some conclusions to be drawn about the relative importance of different specialty crop policy options to California specialty crop interests.

The reminder of this report is divided into four sections. The first provides some information of the scale and importance of the California specialty crop industry from both a state and national perspective. The second discusses California specialty crop farm policies issues. The

[2] This is the definition contained in the 2004 Specialty Crop Competitiveness Act (PL 108-465)
[3] It is important to note that targeted surveys mean that the survey was not entirely random survey of the population of specialty crop producers or producer organizations. Rather it was a survey of a select group of producers and producer organizations.

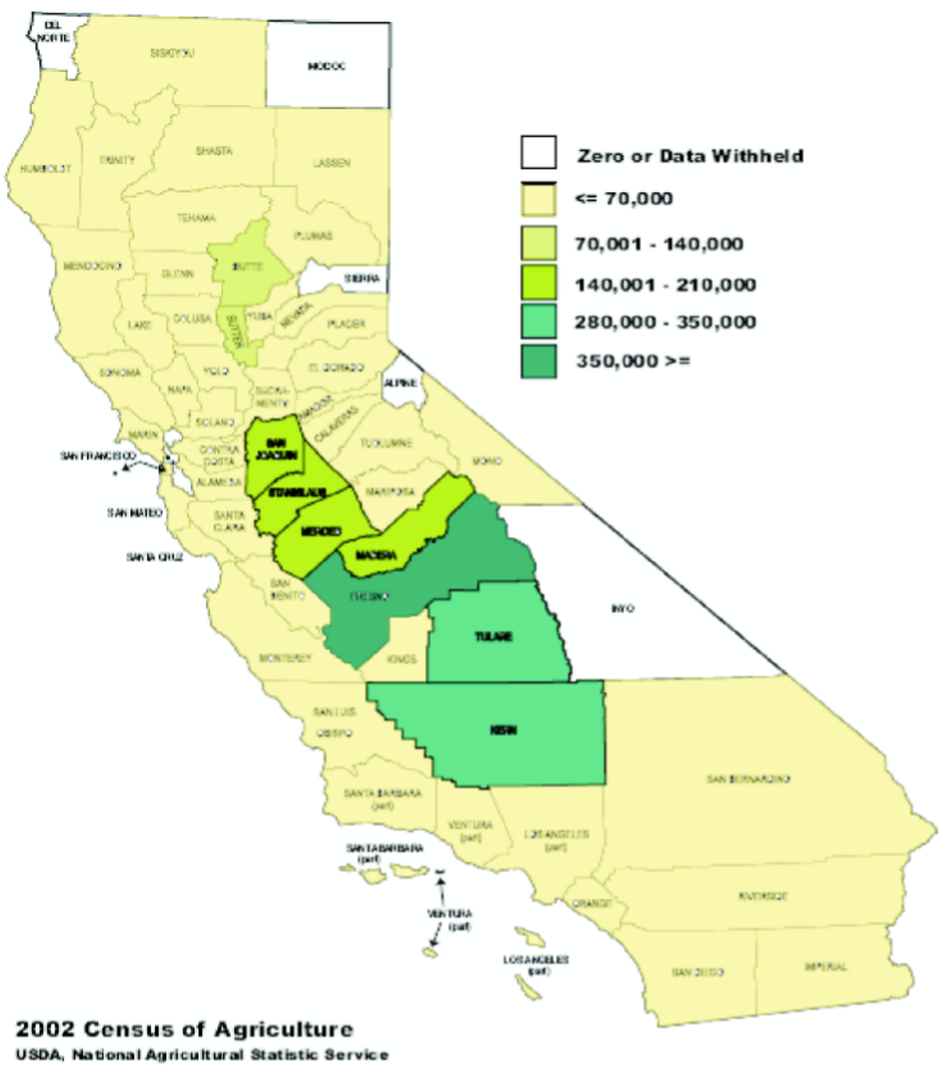
third section provides a relative comparison of the importance of differing farm policies to the California specialty crop industry. The concluding section provides a brief overview of current legislative efforts to incorporate specialty crop specific policies into farm bill legislation.

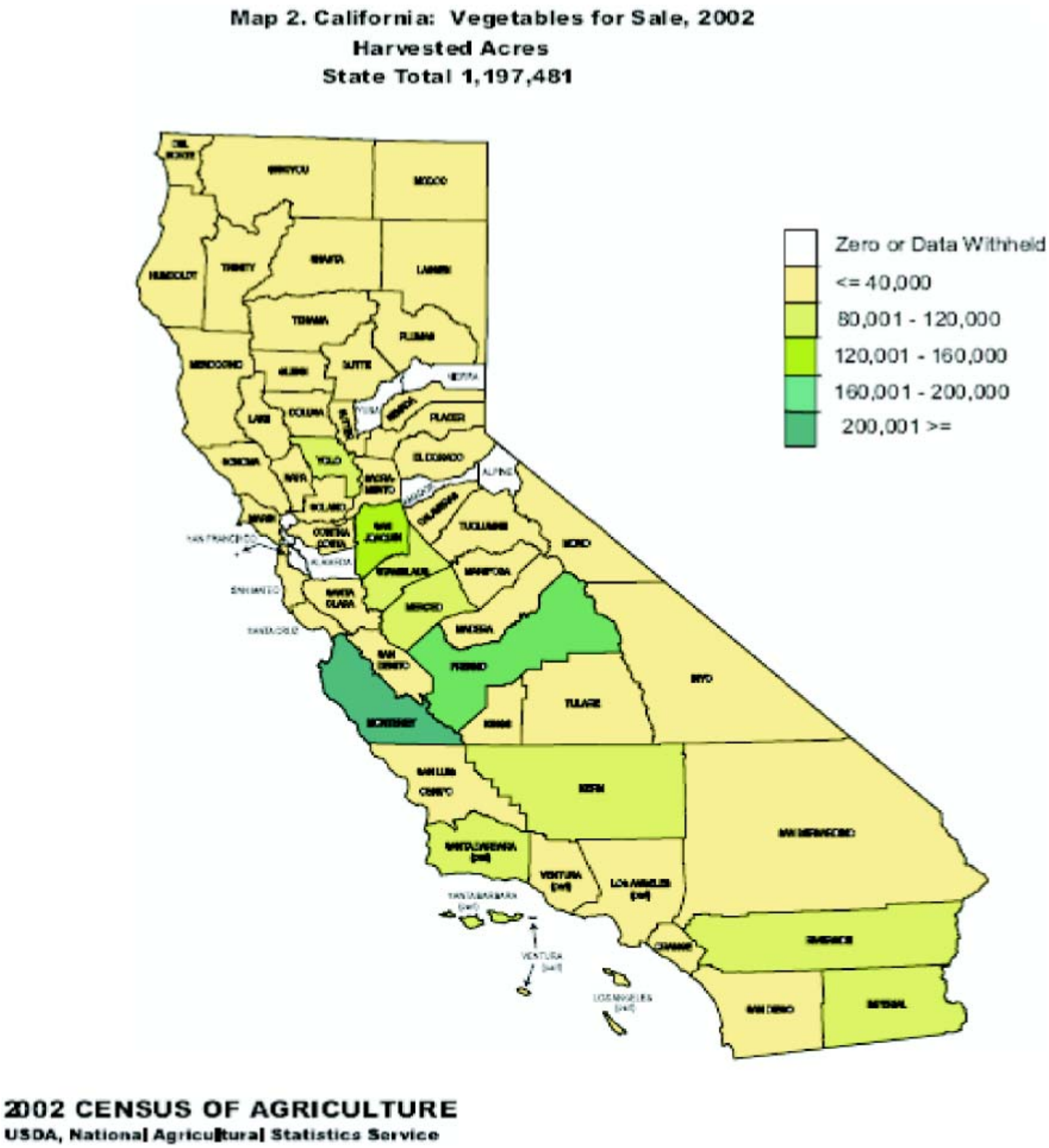
II. The California Specialty Crop Industry

Location

Map 1 and 2 provides the location of California harvested orchard and vegetable production. The maps show that fruit and vegetables are grown in the majority of California counties while the majority of land in orchards (and vineyards) is concentrated in the San Joaquin Valley with the majority of vegetable production located in Monterey County, the Southern San Joaquin Valley Counties, and Riverside and Imperial Counties.

Map 1. California Land in Orchards
Harvested Acres, 2002
State Total: 2,871,626





Acreage

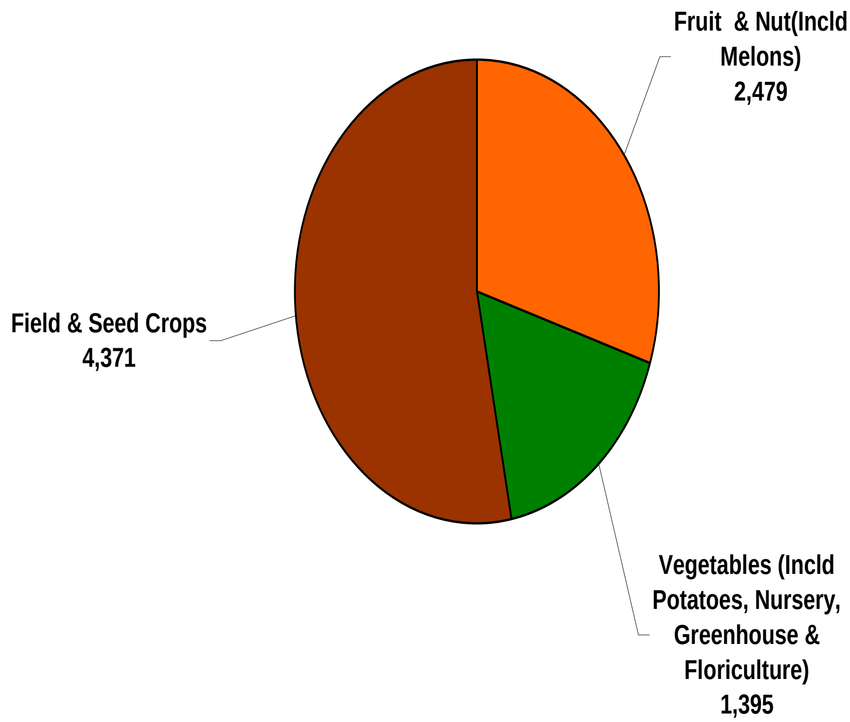
In 2005, there were approximately 8.2 million acres of cropland harvested in California.[4] Figure 1 shows the amount of harvested acreage by major crop category (field crops, fruit & nut, and vegetable, melons, and floriculture). Specialty crops accounted for 47 % of total harvested cropland. Fruit and nuts accounted for 30.1% of total harvested cropland and 64% of specialty crop acreage. Vegetable, melons, and nursery and floriculture accounted for 16.9 % of total harvested acreage and 36% of specialty crop acreage.[5] California accounts for 46.5% of total U.S. harvested specialty crop acreage and 63.3% of total U.S. bearing fruit and nut acreage.

---

[4] Harvested acreage information comes from USDA, NASS, California Field Office report: *California Agricultural Statistics*, 2005. October 2006. Fruit and Nut is bearing acreage.

[5] Nursery and Floriculture acreage data comes from the Floriculture and Nursery Crop Yearbooks, June 2005 and 2006

Figure 1. 2005 California Harvested Acreage by Category (1,000)



Top Crops - Harvested Acreage

Table 1 shows the top eight harvested fruits and nuts and vegetables and melons produced in California. The top 8 fruits and nuts account for 86.6% of the total fruit and nut bearing acreage and the top 8 vegetable and melons account for 71.8% of the total harvested vegetable acreage.

Table 1. Top 2005 Fruit &Nut and Vegetable & Melons Crops
1,000 Acres

Fruits and Nuts	*Bearing Acres*
Grapes (all)	**800**
Almonds (Shelled)	**580**
Walnuts	**215**
Oranges	**182**
Pistachios	**105**
Plums (Dried)	**67**
Peaches (All)	**66.4**
Avocado	**62**

Vegetables and Melons	*Harvested Acres*
Processing Tomatoes	***264***
Vegetables and Melons (Other)	**172**
Head Lettuce	**131**
Broccoli	**122**
Carrots	**71.1**
Romaine Lettuce	**63**
Leaf Lettuce	**55**
Cantaloupe Melon	**51**

California Specialty Crops that Lead the Nation in Production

Table 2. Specialty Crops in which California Leads the Nation

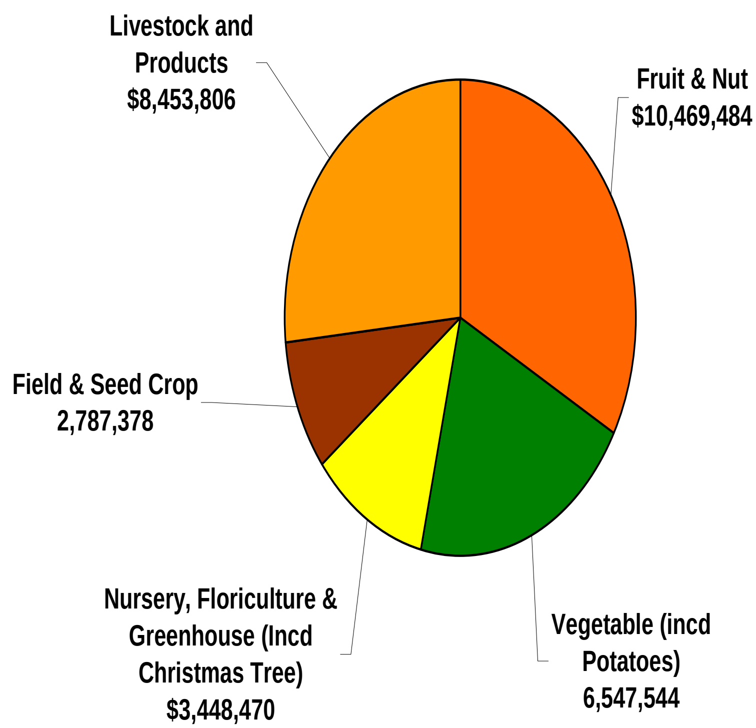
Almonds	Dates	Lettuce. Leaf	Plums
Apricots	Eggplant	Lettuce, Romaine	**Plums, Dried**
Artichokes	Escarole/Endive	Melons, Cantaloupe	**Pomegranates**
Asparagus	**Figs**	Melons, Honeydew	Raspberries
Avocados	Flowers, Bulbs	Nectarines	Spinach
Beans, Dry Baby Lima	Flowers, Cut	Nursery, Bedding Plants	Squash
Beans, Dry Large Lima	Flowers, Potted Plants	Nursery Crops	Strawberries
Beans, Green Lima	Garlic	**Olives**	Tomatoes, Processing
Bedding/Garden Plants	**Grapes, Raisins**	Onions, Dry	Turnips
Boysenberries	Grapes, Table	Onions, Green	Vegetables, Greenhouse
Broccoli	Grapes, Wine	Parsley	Vegetables, Oriental
Brussels Sprouts	Greens, Mustard	Passion Fruit	**Walnuts**
Cabbage, Chinese	Herbs	**Peaches, Clingstone**	
Cabbage, Fresh Market	Jojoba	Peaches, Freestone	
Carrots	Kale	Pears, Bartlett	
Cauliflower	Kiwifruit	Peas, Chinese	
Celery	Kumquats	Peppers, Bell	
Chicory	Lemons	**Persimmons**	
Daikon	Lettuce, Head	Pistachios	

California is the sole producer (99 percent or more) of the commodities in bold

California Specialty Crop Farm Income

California 2005 farm cash income was slightly over $31.8 billion dollars. Figure 2 shows the cash income by agricultural commodity.[6]

Figure 2. 2005 Farm Cash Income by Category ($1,000)



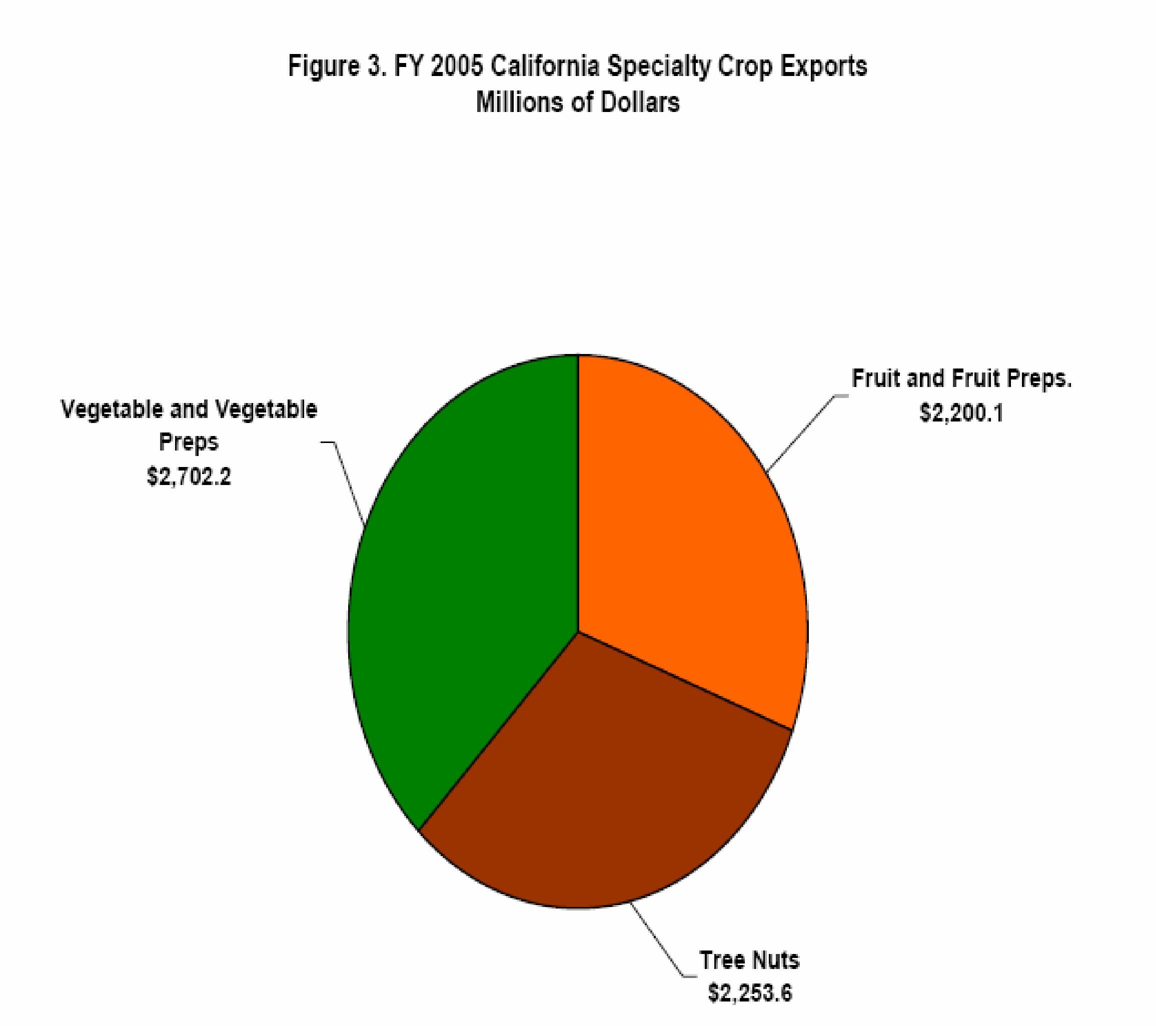
[6] Farm income information comes from USDA, NASS, California Field Office report: *California Agricultural Statistics, 2005.* October 2006.

California specialty crops account for $20.5 billion (64.5%) of the California's agriculture cash income and 88% of California crop income. Fruit and nut production account for 45% of California crop cash income, vegetables and melons account for 28.2% and nursery and greenhouse accounted for 14.8%. California specialty crop farm income is 41.8% of total U.S. specialty crop farm income. California fruit and nut farm income is 65.3% of total U.S. fruit and nut farm income.

Evaluating the acreage and cash income information it is clear that that California is the leading state in the production of U.S. specialty crops.

California Specialty Crop Exports

In FY 2005, the total export value for California's agricultural products was approximately $10.2 billion.[7] Figure 3 shows California specialty crop exports.



[7] Export data is taken from U.S. Exports by States, Foreign Agricultural Service, 2006.

Exports of fruit nuts and vegetables represent approximately 70% of the export value. Leading California specialty crop exports include almonds, table grapes, oranges, processed tomato products, walnuts, raisins, lettuce, and pistachios.

III. California Specialty Crop Industry Policy Issues

Specialty crops, historically, have not been the focus of federal farm legislation. The paradigm shifted with the passage of Specialty Crop Competitiveness Act (SCCA) of 2004 (PL 108-465).[8] The SCCA represents a focused attempt to address particular issues of importance to the specialty crop industry. It includes elements that are specific to the specialty crop industry, such as state block grants to fund state-based initiatives that have as their objective the improvement of the competitiveness of each state's specialty crop industries. The SCCA also included provisions similar to traditional program crop legislation such as agronomic research and invasive species initiatives.

The California specialty crop industry, in general, would like to see many of the provisions of the SCCA incorporated into the 2007 Farm Bill. This desire was reflected in the listening sessions and surveys when the general question was asked: *Is an active federal government role necessary to maintain or improve the competitiveness of the California specialty crop industry?* Although industry participants' description of the government's role differed their general response was that federal farm policy is important towards maintaining the long-run competitiveness of the California specialty crop industry.

The following provides a set specialty crop policy issues that could be included in the 2007 Farm Bill debate. These policy issues are based on the listening sessions and surveys previously discussed. The specific policy areas to be addressed are: (1) farm safety net programs, (2) conservation programs, (3) trade programs (4) food assistance and nutrition programs, (5) research programs, (6) biofuels, (7) small farm program and rural development programs, and (8) block grants.

This list is comprehensive but not exhaustive. There are a number of issues that are important to the California specialty crop industry but do not fit into the above categories as they concern broader process and regulatory issues rather than specific farm bill policy prescriptions. For example, one of the most frequently mentioned issues was the "flex acres provision" that has appeared in the last two farm bills. Specifically, program crop growers are excluded from growing fruits and vegetables on contract acreage, or acreage that is enrolled in the growers' name and

[8] This is not to say that specialty crops have not received any federal support. Federal support has been provided in mostly indirect ways. That support includes Specialty Crop Block grants to the States; Crop Insurance; Market Loss Payments; Marketing Orders and Agreements; Generic Promotion, Research and Information Programs (Check-off Programs); Export Promotion; Food Purchases; Food Assistance and Nutrition Programs; National Research Programs; Specialty Crop Planting Restriction; Animal and Plant Health Inspection Service, and Pest and Disease Exclusion Programs. However, many California specialty crop interests point out that the amount of federal support is not comparable to farm bill program crops especially given the contribution the specialty crop industry makes to the California and U.S. farm economy.

eligible to receive program-crop subsidies under provisions of the 2002 farm bill. As a result of the World Trade Organization (WTO) U.S. – Brazil Cotton dispute decision in early 2005 there is at least some likelihood that the specialty crop planting restriction will be removed from farm legislation.

Other policy issues are important to California specialty crop industry, but will likely be dealt with under separate federal or state legislation. First, while agricultural market development (i.e. the Market Access Program) typically forms part of the Farm Bill, most trade related issues arise in the context of bilateral or multi-lateral trade agreements that are negotiated and passed separately from the farm bill.

A second policy area that is outside the scope of current farm legislation but is very important to the California specialty crop industry is agricultural labor. Virtually every discussion about public policy issues that can impact the California specialty crop industry includes a discussion on the cost and supplies of farm labor especially harvest labor. The current debate over immigration reform and whether a guest worker program should or should not be included is being watched very closely by the California specialty crop industry.

To the extent that these policy issues are tied to farm bill initiatives, it is important that California specialty crop interests keep industry priorities firmly in mind while negotiating non-trade and non-labor issues in the farm bill itself. Other policy issues that can affect California specialty crop sustainability and competitiveness that fall outside the scope of the Farm Bill are crop insurance, water supply and quality, urbanization and land-use issues, energy prices, and tax issues. Changes to crop insurance are typically made through separate legislation, most recently in the Agricultural Risk Protection Act (ARPA) of 2000. Water supply and quality, urbanization and land-use, energy prices, and tax issues are covered by a number of state and federal policies.

Farm Safety Net Programs

There is general lack of interest in the California specialty crop industry for commodity support type programs. Thus, direct payments, marketing loan, and countercyclical payments do not garner much support as viable policy options. The California specialty crop industry is concerned that such programs would distort specialty crop planting decisions by removing the inherent yield and price risks faced by existing specialty crop producers thus leading to possibly higher production and weaker prices in the future. This suggests that most specialty crop producers feel relatively comfortable dealing with the price and yield variability in their industries and have found alternative risk management tools.

The farm safety net program with the greatest support in the California specialty crop industry is federal crop disaster programs. There is almost universal support for these programs. The use of federally subsidized revenue insurance programs is considered to be a viable option. However, there are concerns that these insurance programs lack consideration of the high cost of production and smaller scale of operation of California specialty crop producers in contrast to commodity producers and that overall program implementation has been poor.

Conservation Programs

There is general support for conservation programs. The following environmental policies are those most favored by the California specialty crop industry: Farmland Preservation Program (FPP), Environmental Quality Incentives Program (EQIP) especially in the areas where water and air quality improvements and reduction in soil erosion are a priority, and the Conservation Security Program (CSP). These programs can benefit specialty crop producers in several ways. They provide either federal cost share for projects that remediate environmental damage, provide payments for providing environmental amenities, or protect farmland resources against urban encroachment. Additionally, the adoption of these programs by specialty crop producers provides social benefits that include open space and wildlife habitat.

The California specialty crop industry would like to see these programs receive greater federal funding given they are generally over-subscribed. There is a general view by the industry that these programs need some modification to account for the unique characteristics of California specialty crop production such as high land values, costs of production that are high relative to most commodity crops, and the unique challenges of growing crops in the urban-rural interface.

Trade Programs

Easily the most important import policy to the California specialty crop industry is the prevention of invasive pests entering into the state. The invasive pest issue is of critical concern to the industry. This concern translates into a strong desire on the part of the industry for increased funding for APHIS pest prevention activities. Other import trade policies that are considered very important to California specialty crop producers is maintaining antidumping laws to prevent dumping of foreign products on U.S. markets and use of tariffs to protect import sensitive crops.

Promotion of U. S specialty crops in international markets received significant support from the California specialty crop industry. There is strong interest on the part of the California specialty crop industry to see foreign competitors eliminate domestic support and export subsidies. Other export trade policies of interest included reduction in tariff and nontariff trade barriers both of which are market access issues.

It should be noted that most of the trade policies that the California specialty crop industry consider important to its sustainability and competitiveness fall outside the scope of farm bill legislation, e.g. trade barriers, market access, and export subsidies.

Food Assistance and Nutrition Programs

There is significant support for federal government programs that have as their objective promotion of better nutrition and eating habits. Among the programs supported are USDA school lunch program, the Women, Infant and Child program, double food stamp for purchasing fruits and vegetables, and the fruit and vegetable school snack program.

Additionally, a social benefit attributable to greater consumption of fruits and vegetables, if the USDA 2005 Foods Pyramid or similar diet were to be adopted by more people, would be a reduction in national health costs due to future reduction in obesity and other national health problems (e.g. high blood pressure and cancer).
The importance of these programs to the California specialty crop industry given that California is already the U.S. largest supplier of U.S. fruits and vegetables is the potential for increased demand of California fruits and vegetables.[9]

The research policy area receives the greatest attention from California specialty crop industry. The California specialty crop industry perceives that research is very important towards remaining competitive in an integrated world economy. There is recognition on the part of the industry that research programs can impact future sources of income and cost of production. The California specialty crop industry would like to see significant increases in federal expenditures for specialty crop research programs and extension education.

Areas that were mentioned include research into labor saving production technologies, crop protection strategies, invasive and general pest management, post-harvest storage and transportation technologies, new product development, and economic information about polices and market issues that affect specialty crop competitiveness and profitability. There is also a recognition that the productivity of research depends on the quality of extension education. Although all of the areas received significant support the greatest support was for invasive and general pest detection and prevention research.[10]

Energy Programs

This is a policy area that received mixed support. The California specialty crop industry, in general, supports the idea of producing fuel from crop residues, animal wastes, and other agricultural biomass. The support for bio-energy is partly based on the idea that if plant and animal residues, agricultural processing wastes and by-products can be converted into energy products at either a breakeven or better price that this will also alleviate some of the regulatory compliance issues and costs associated with agricultural waste disposal, and air and water

[9] Research at the National Food and Agriculture Policy Project (Arizona State University) has shown that a $10 food stamp supplement – about 10% of the current monthly benefit – earmarked specifically for fruits and vegetables, would lead to a $308 million rise in retail sales of fruits and vegetables.
[10] *Exotic Pests and Diseases: Biology and Economics for Biosecurity,* Daniel A. Sumner, editor. Iowa State Press, May 2003 provides 14 case studies that emphasis the importance of policy measures to protect against the introduction and spread of exotic pests.

quality standards. Support is also garnered from bio-energy supporters who are concerned about reducing the U.S. reliance on foreign energy resources. Concerns that are expressed are about the competitiveness of bio-energy products versus convention energy resource products and some of the regulatory and marketing issues that must be faced to operate and market biomass energy products. Thus, the California specialty crop industry is interested in further federal funding of research in bioenergy that would include both technological and economic evaluation of the production and marketing of bio-energy products.

Small Farm Programs and Rural Development

California's small specialty crop producers support several Farm Bill programs including the Sustainable Agriculture and Education Program, the Environmental Quality Incentives Program, the Conservation Security Program, the Value Added Grants Program, the Community Food Project Competitive Grant Program, and Organic Research.

A complaint often aired by small California specialty crop producers is that they are underserved by federal farm policy and would like to see federal government programs that serve them to be expanded and given more federal funding. This runs a gauntlet of policy options and it is unclear which of the policy options is most highly favored. Among those policy options discussed are federally subsidized programs that support sustainable agricultural research and practices, organic agriculture programs, tax deferred farmer savings accounts, revenue insurance, and disaster payments. A special concern that was expressed is the need to have access to credit for farming operations and investments. Finally, the issue of extension education appears to be important to small specialty crop producers.

IV. Relative Importance of California Specialty Crop Policies

It is not possible to definitively rank the farm policies that are most important to the California specialty crop industry. There are two reasons for this. First, it is very probable that different segments of the California specialty crop industry would rank the importance of the policy issues differently. Second, due to the anecdotal information received from the listening sessions and surveys any ranking would be subjective on the part of the author. However, it is possible to offer some general observations as to importance of the different farm policy areas to the California specialty crop industry.

The research policy area is the policy area that receives the greatest attention from specialty crop producers and their associations. It is a policy issue that the California specialty crop industry believes is very important to California specialty crops remaining competitive in an integrated world economy.

Trade polices included in federal farm legislation favored by California specialty crop producers and their associations include foreign market promotion programs and prevention of invasive pests from entering the U.S. The invasive pest issue is thought to be critical by specialty crop producers. This translates into support for greater funding for

APHIS pest prevention activities. However, trade policy issues such as domestic and foreign market access, foreign production subsidies, and export subsidization policies that are determined by multilateral and regional trade agreements and anti-dumping policies considered to be very important by the California specialty crop industry.

The California specialty crop industry has significant interest in federal government food assistance programs that promote better nutrition and eating habits. These programs have the potential to increase the demand for California fruits and vegetables. Among the programs mentioned for support are the USDA school lunch program, the Women, Infant and Child program, double food stamp for purchasing fruits and vegetables, and the fruit and vegetable school snack program.

There is general support for conservation programs. There is a growing recognition that there is a multi-functionality element in the production of specialty crops in an urban-rural environment. The California specialty crop industry would like to see these programs receive greater funding given they are generally over-subscribed. There is a general view by the California specialty crop industry that these programs need to be modified to take into account the unique characteristics of specialty crop production such as high land values, costs of production that are high relative commodity crop production, and unique challenges of growing crops in urban-rural interfaces.

The California specialty crop industry, in general, is not interested in commodity support programs such as direct payments, countercyclical payments, and marketing loan. The California specialty crop industry is concerned that such programs would distort specialty crop planting decisions by removing the inherent yield and price risk faced by existing specialty crop producers thus leading to possibly to higher production and weaker prices in the future. This suggests that most specialty crop producers feel relatively comfortable dealing with the price and yield variability in their industries and have found alternative risk management tools. Crop disaster programs are highly favored by the California specialty crop industry and there is some support for revenue insurances programs.

Small Farm and Rural Development policy options discussed are federally subsidized programs that support sustainable agricultural research and practices, organic agriculture programs, tax deferred farmer savings accounts, revenue insurance, and disaster payments. A special concern that was expressed is the need to have access to credit for farming operations and investments. Finally, the issue of extension education appears to important to small specialty crop producers. Rural development programs received some support from specialty crop producers; however, it appears was low on the priority list. Those California specialty crop producers that favored rural development programs favored an increased government role in improving access to capital for rural business development, and funding rural housing and health services.

Energy policy received mixed support from the California specialty crop industry. The California specialty crop industry, in general, supports the idea of producing fuel from crop residues, animal wastes, and other agricultural biomass. Concerns that are expressed are about the competitiveness of bio-energy products versus convention energy resource products and some of the regulatory and marketing issues that must be faced to operate and market biomass energy products. Thus, the California specialty crop industry is interested in further federal funding of research in bio-energy that would include both technological and economic evaluation of the production and marketing.

California specialty crop producer organization generally favors continuance of the block grant program that was initiated in 2002 and reauthorized in the 2004 Specialty Crop Competitiveness Act. However, while there is general support for specialty crop state block grants it is unclear, other than research programs, what federal farm policy areas the California specialty crop industry thinks should be devolved to the state through a specialty crop block grant program. It is evident that more research into this issue will be necessary before any definitive suggestions can be made.

Two policy areas that are very important to the California specialty crop industry that are outside the farm bill legislation are agricultural labor and trade. These are likely to be addressed by separate legislation and not through the farm bill.

V. Current Legislative Outlook

The interest in permanently incorporating specific specialty crop programs into federal farm legislation has resulted in the formation of the Specialty Crop Farm Bill Alliance. It is composed of over 70 specialty crop organizations representing growers of fruits, vegetables, dried fruit, tree nuts, nursery plants and other products.

The alliance was influential getting HR 6193 the "Equitable Agriculture Today for a Healthy America Act" or the EAT Healthy America Act" introduced. HR 6193 has eight titles that provide for increased funding and/or government support for specialty crop block grants, disaster assistance, conservation, international trade, pest and disease control, nutrition, research and development, renewable energy, and miscellaneous issues. It is yet to be determined whether HR 6193 will become incorporated into federal farm bill or other legislation but many of its provisions would seem to fall under the facilitating role of government with respect to the long-run sustainability of the U.S. specialty crop industry.

* Jay E. Noel is Director, California Institute of Specialty Crops (CISSC) and Agribusiness Professor. CISSC was funded by a $2.9 million dollar grant from the Buy California Initiative grant program. More information about the Institute can be found at www.cissc.calpoly.edu.

Current Opportunities in the California Olive Oil Industry

Paul Vossen
Farm Advisor UC Cooperative Extension – Sonoma County
133 Aviation Blvd. # 109
Santa Rosa, CA 95403

INTRODUCTION

The California olive oil industry has recently developed a much better position to compete in the domestic olive oil market based on a new economic profile. Olive oil production today is rapidly moving towards the super-high-density (SHD) growing system in the orchards and the automated continuous flow processing system in the mills. The SHD system is based on over-the-row mechanical harvest, which significantly lowers production costs compared to trunk shaker or hand harvest methods commonly used in older production systems. SHD olive orchards also incorporate precocious cultivars in combination with close spacing to bring the trees into bearing early, which provides a quicker return on investment. The new continuous flow milling system uses automated stainless steel machines that process olives into oil of superior quality and require very little labor. The super-high-density system is not a panacea, however, as it is more expensive to establish, requires more intensive management, is limited to only a few precocious oil cultivars, must have relatively flat ground for large machinery access, and its long term viability is still unknown. The initial cost of an automated mill is also very high.

The market for olive oil in the United States has doubled in the last ten years and the US is currently ranked fourth in world consumption. Consumers are buying more olive oil primary because of an association with a healthy diet and its status as a specialty product, but almost all if it is imported. In 2006, California had 10,200 acres of olives grown for oil, which were processed in 27 mills. This oil supplied less than one percent of US consumptive demand indicating that over 300,000 acres could be planted to supply current needs. California olive oils have won many awards, are known to be equal to or better in quality than most imported products, and consumers are readily buying the domestically grown product. Other competitive advantages are California's excellent climate, soils, irrigation water, labor force, mechanization, and other technological advances in orchard management and processing systems. The University of California has played a key role in supporting this new industry with research and educational programs on cultural practices, pest control, cost analysis, evaluation of different types of processing systems, and sensory evaluation of olive oil. This new olive oil industry is growing and appears to have a lot of positive potential.

CALIFORNIA OLIVE OIL - IN PERSPECTIVE

Almost all of the olive oil in the world is produced on about 24 million acres in the countries surrounding the Mediterranean Sea. The big three: Spain, Italy, and Greece produce about 75% of the world's olive oil. The other European, North African, and Middle Eastern countries produce about 20%, and the new world countries of Argentina, Australia, Chile, South Africa, New Zealand, and the USA produce the remaining 5% (IOOC, 2003). In the USA, California is the only state with significant production. In 2006, California produced an estimated 400,000 gallons of olive oil, which is only 0.06% of the world's olive oil and less than 1% of the USA's domestic consumption of about 60 million gallons. North Americans consume about ¾ of a liter per person per year while the per capita consumption for the Greeks, Spanish, and Italians, is 26.1, 15.0, and 13.5 liters respectively. Worldwide olive oil only represents about 3% of the world's consumption of fats and oils, but in the USA it is about 8% and has doubled over the last few years (Market Research.com, 2002; Vossen and Devarenne, 2005).

Most of the 10,200 estimated acres of oil olive orchards in California have been planted in the last ten years; about 40% in just the last two years. Most of the older orchards that went in at the start of the gourmet olive oil resurgence in the late 1980's and early 1990's were planted in coastal counties. They are almost all small-scale plantings (2-10 acres), spaced at a high density of about 200-300 trees per acre, and are growing primarily Italian cultivars such as 'Frantoio', 'Leccino', 'Maurino', and 'Pendolino'. Most of the newest plantings are located in the Central Valley, are much larger in scale (50 to 200 acres – one is 800 acres), and they have been planted at a super-high-density of 670-900 trees per acre with the varieties 'Arbequina', 'Arbosana', and 'Koroneiki'. The nurseries supplying the trees for these new plantings are scrambling to meet the demand for trees as it is anticipated that several thousand acres will be planted with the demand continuing into the foreseeable future. When the currently planted acreage in California comes into bearing over the next 3-5 years, the state will be producing about 1 million gallons of olive oil per year (Vossen and Devarenne, 2005; Vossen, 2006a).

Estimated average production in the Central Valley for the SHD system is about five tons per acre producing 850 liters (225 gallons) of oil. The coastal areas produce about half that per acre, but producers there have typically sold their oils at higher prices. Some European growing regions have defined quality based on the flavor of oils produced in their specific appellations, but oil quality is subjective and can not yet be identified by growing region in California (Romero et al., 2005; Uceda and Aguilera, 2005). California's olive oils, as defined by flavor and style, have been closely associated with variety, harvest maturity, and processing technique. Many examples of California olive oils produced in the coastal counties, the Sierra foothills, and in Central Valley orchards that have won awards internationally. Numerous brands from small-scale coastal and foothill growers have won awards in blind competitions in Europe, yet recently, the largest producer of a SHD system olive oil blend from the Central Valley in California won an award for "Best of Show" oil at the Los Angels Fair "Olive Oils of the World" competition, which was judged by international tasters (Apollo, 2006; Davero, 1998; LA County Fair, 2006; The Olive Press, 2002).

PROFITABILITY

There needs to be a distinction made between the production costs for high density coastal oil olive plantings and the SHD plantings in the Central Valley. According to UC cost studies, coastal areas can produce about 2.5 tons of olives per acre, which translates into 852 one-half liter bottles at 45 gallons of oil per ton. The per-acre production costs there are $9,500, which makes the per-bottle cost $11.15. If bottling and marketing were not included, the oil would have to sell in bulk for $53.33 per gallon ($14.09/l) in order to meet costs. These orchards have more overhead due to higher land costs and management costs that are spread over only a few acres. Small scale growers and millers in these areas have become artisan producers of unique oil styles that can not be made with fruit from the SHD system cultivars. The higher prices required to meet costs and lower volumes for the small scale growers have limited them primarily to specialty and direct marketing strategies.

In the Central Valley, production per acre is higher and costs can be spread out over larger acreages. Land, water, and labor costs are also lower. With the SHD system, the fruit can be harvested with an over-the-row machine at 10% the cost of hand harvest. Combine that with large automated processing machinery that spreads the milling costs over a much larger volume of oil, the cost for a ½ liter bottle is $4.93. This is based on a production cost of $8,400 per acre, but twice the yield (5 tons), and the same 45 gallons oil yield per ton, producing 1,704 one-half liter bottles per acre. For producers not interested in marketing their own bottles of oil, the super-high-density system also can work economically if the fruit is sold above $460.00 per ton or if the oil is sold in bulk for over $15.00 per gallon ($3.96/l) (Vossen et al., 2001; Vossen et al., 2004).

The current bulk price for olive oil in California is $23.00 per gallon potentially making the SHD system profitable compared to most imported oils sold in supermarkets. Without the potential of the super-high-density production system, the California industry would likely stay small and very specialized. One of the primary objectives of California producers is to convince Americans to buy new brands of California olive oil instead of the long established supermarket brands such as Bertoli, Carapelli, Colavita, DaVinci, Felippo Bario, Star, Sasso, and others that commonly sell for $6-13 per half liter bottle. Currently, the California Olive Ranch (COR) brand oils are successfully selling in some supermarkets at $10-12.00 per ½ liter bottle. (Vossen, 2006c - unpublished).

KEYS TO SUPER-HIGH-DENSITY ORCHARD SUCCESS

The super-high-density system has many obvious advantages such as less labor input needed for harvest and pruning which is either entirely or partially offset by machines. The trees come into bearing starting the second year with significant and harvestable fruit the third year reaching full production by the fourth or fifth years, compared to wider spaced orchards that require at least twice as many years to reach their full per-acre productive capacity (Vossen, 2002).

The super-high-density system is more intensively managed than other oil olive systems; it requires a great deal of orchard management skill and more initial investment capital. The following are keys to making it work:

- ***The site:*** should be on well-drained soil that is not excessively steep in order to accommodate the mechanical harvester. Excessively fertile "bottom" ground that is very deep will likely not limit the vigor of the olives, which could lead to poor fruiting and excessive shading in high rainfall areas. An adequate amount of high quality irrigation water is required to meet the growth demands of young trees and fruit production demands in order to achieve high annual yields and good shoot growth that minimizes alternate bearing. A range from 12 to 36 inches of water per acre are required depending on climatic demand and it should meet the minimum requirements of < 2 ppm boron, < 3.5 ppm bicarbonate, < 480 ppm total salt, < 9 SAR, and < 345 ppm chloride. The soil should meet the minimum requirements of having a pH in the range of 5-8.5, SAR < 15, chloride < 15 meq/l, boron < 2 ppm, a ratio of magnesium to calcium of < 1:1, and a potassium level > 125 ppm. Elevations above 2,000 ft. elevation are not recommended due to the increased risk of cold injury to trees or fruit before harvest. Orchard temperatures should not get < 25^{o}F for young trees, < 15^{o}F for mature trees, and < 29^{o}F for fruit before harvest usually in mid October to mid December. Olive trees also do not do well in climates with hot dry winds or rain during bloom in late April and early May (Vossen, 2007).

- ***Varieties:*** The only three varieties that we know work well in this SHD system are 'Arbequina', 'Arbosana', and 'Koroneiki'. They are precocious and tend to bloom and fruit on whatever shoot growth occurred the previous year. Other varieties will be much more difficult or impossible to maintain within the confines of the over-the-row harvester (< 10 ft.) (Pastor, 2005). 'Arbequina' is an early ripening cultivar that is cold hardy and produces a mildly pungent and almost never bitter oil with intense fruitiness. 'Arbosana' is a lower vigor cold hardy cultivar that is harvested about two weeks later than 'Arbequina' and produces a much more pungent and bitter style oil. 'Koroneiki' is a cold sensitive, late maturing variety that has about the same vigor as 'Arbequina' but is more alternate bearing and produces oils that are quite bitter, very pungent, and that have undertone flavors of banana, tropical fruits, and green herbal tea (Tous et al., 2003).

- ***Tree spacing:*** is determined by matching the variety with the inherent vigor of the ground along with climatic influences. If the soil is deep and fertile, the trees should be planted at a slightly wider spacing, perhaps 5 ft. x 13 ft. (670 trees/acre), but the best spacing for this system is 4 ft. x 12 ft. (907 trees/acre). The in-row spacing should be such that fruiting branches growing off the central leader just touch, and the between-row spacing should not be greater that 1.3 times the allowable tree height to accommodate the harvester. Rows growing into hedgerows should be oriented North-South and no more than 80% of the orchard floor should be shaded in mid summer (Tous et al. 2003, Vossen, 2006b).

- ***Push the young trees:*** start them off with plenty of moisture, adequate fertility, and good weed control so they grow rapidly and fill their allotted space within the first 3-4 years. Young actively growing trees will require from 4-10 gallons of water per tree per day in the hot summer months depending on the climate. Nitrogen levels must be adequate as indicated by tissue analysis, and there should be zero weed competition within three feet of the trees (Vossen et al., 2006; Vossen and Connell, 2006).

- ***Train the trees***: to an upright mini central leader form by tying the leader as it grows vertically to a support stake and keep the lower 3 feet clean of all lateral branches for good closure of the mechanical harvester catch frame. Very little to no additional pruning is done in the first 3 years (Vossen, 2006b).

- ***Pruning mature trees***: No large lateral branches are ever allowed to grow in this system, all of the fruiting should occur within about 2 ft. of the central leader. Lateral branches longer than that or > 3 years old should be cut back to a short stub near the central leader by hand. Trees are mechanically topped every other year in the summer to maintain a maximum height for the harvester and the skirts are mechanically trimmed to prevent interference with the closure of the harvester catch frame around the base of the trees. Trees are pruned more heavily in years just prior to an anticipated heavy crop (Vossen, 2006b).

- ***Fertility level for mature trees:*** especially nitrogen is reduced after the 3^{rd} year in order to create less vegetative vigor. More nitrogen is provided in years with a very heavy crop to encourage more vegetative shoot growth and better production the following year. Years with a light crop are given less nitrogen fertilizer (Vossen and Connell, 2006).

- ***Controlled deficit irrigation:*** management practices are followed after the 4^{th} year to limit vigor, save water, and maximize oil quality. Mature trees produce the maximum amount of oil per acre receiving between 50-70% ET, and the best oil flavor quality is achieved when trees are irrigated between 35-55% ET. Controlling the amount of irrigation water the trees receive is the best way to minimize excessive vigor in light cropping years and improve shoot growth in heavy cropping years (Berenguer et al., 2006; Grattan et al., 2006).

- ***Monitor carefully for leaf diseases:*** Closely spaced hedgerow orchards need to be watched closely and sprayed preventively for foliar diseases, see their description below.

OLIVE PESTS

There are very few pests that bother olives and since the fruit is crushed, cosmetics are unimportant compared to table fruit. Some pests are economically important and must be controlled, but there is nothing that would significantly limit production.

- ***Olive fruit fly:*** This is the most important pest of olives in California. The olive fruit fly (*Bactrocera oleae*), invaded California in 1998 and has now spread throughout the whole state. The adult is very similar to other Tephritid fruit flies. It is 4-5 mm long with a reddish brown color and a small black spot at the tip of its wing. It has 3-5 generations per year and can remain active year round in warmer parts of the state. Eggs laid under the fruit skin develop into maggots and destroy the fruit flesh. Some damage is tolerable since the fruit does not rot or produce off flavors in the oil until a very advanced level of damage occurs. Control is achieved using mass trapping, spraying with kaolin clay to create a barrier film on the fruit, or by spraying spinosad in a bait formulation. Combinations of these methods can also be used to improve effectiveness and reduce costs. Recent research in California has shown that untreated trees can have close to 100% damage by mid October while mass trapping can reduce damage down to about 30% damage and the two spray techniques down to less than about 3% damage. All of these methods are organic (Vossen and Kicenik Devarenne, 2006).

- ***Scale insects:*** Several species feed on leaves, twigs, and fruit causing minor damage and rarely serious injury, but they can under some conditions. These insects are all small (3-5 mm) shell-like creatures that, once settled, stay in one place to feed and stunt the tree's growth. Black scale (*Saissetia oleae*) is the most prevalent of the scale insects and if present in large numbers can leave a thick layer of sooty mold fungus that feeds on its sweet excreted juices almost smothering the tree. It is usually kept in check by natural enemies and by opening up the tree with pruning, which increases mortality because of higher temperatures. If necessary they can be sprayed with horticultural oils. The other scales are: Oleander (*Aspidiotus nerii*) and Olive Scale (*Parlatoria oleae*) (Krueger and Vossen, 2007).

- ***Foliar diseases:*** There are two very similar leaf spotting fungal diseases that cause defoliation and weakening of the tree. They are Peacock Spot (*Spilocaea oleaginea*) and Cercospora (*Cercospora cladosporioides*). Fixed copper fungicides are used and should be applied before major fall rains allow the disease to spread from last year's leaf infections to the new shoot growth. In wet coastal climates two sprays may be necessary, but in drier areas only one is needed (Krueger and Vossen 2007).

- ***Verticillium wilt*:** This fungal disease (*Verticillium dahliae*) is soil borne, can infect almost every cultivar, and can kill the trees. Fields with known disease pressure such as the West Side of the San Joaquin Valley or areas where cotton or Solanaceae plants had been recently grown, should not be planted in olives because of the high risk (Krueger and Vossen 2007).

- ***Root rot:*** Olive trees are not tolerant of wet soils and can easily be killed if trees are not planted into well drained soils. The primary fungus that ultimately can kill trees and causes root rot is (*Phytophthora sp.*). This disease is prevented by not planting in soils with poor drainage or by improving drainage with underground tile systems and raised planting berms (Krueger and Vossen 2007).

PROCESSING OLIVES INTO OIL

The olive cultivar dictates much of the flavor of an olive oil, but after that fruit maturity is the most important consideration in the ultimate quality and especially the style of olive oil produced. Olive oil can be described as both ripe fruity and green fruity and they are distinctly different. Olives harvested early when they are still green or just turning yellow to red are characterized as having herbaceous flavor characteristics such fresh grass, herbal, artichoke, nettle, mint, tomato leaf, etc. Early harvested fruit is also much more bitter and pungent, because it is higher in polyphenols. Later harvested fruit that is picked when the fruit is more mature and colored to red and black produces oils that are much less bitter and pungent. They also that have some ripe fruit undertone flavors that are often described as floral, buttery, nutty, apple, banana, berry, or tropical (Gutierrez, 1999; Tous et al., 1997). California growers can chose when they harvest their fruit to produce oil flavor profiles (oil styles) that they feel are attractive to their niche of consumers.

To produce high quality oil the olives must be harvested without breaking the fruit skins and ideally the fruit should be processed within 2 to 4 hours ideally and within a maximum of 12 to 24 hours. Fruit should be separated by quality with each grade processed separately (Hermoso et al., 1998). California currently has 28 olive oil processing facilities and many of them have been upgraded and enlarged in the last few years with very modern, almost completely automated systems that require very little manual labor. Automated mills use sensors, flow meters, temperature controllers, real time product analysis, automatic arms and various other robotics plus sophisticated software to do most of the work from a computer screen. The steps in modern olive oil processing include: fruit cleaning, washing, and crushing; paste malaxation and separation; oil cleaning; and oil storage.

- ***Fruit Cleaning and Washing:*** Most mills pass the olives over a vibrating screen and blower that removes leaves and other debris. Excessive amounts of leaves or twigs can give the oil a chlorophyll or woody flavor. Olives are washed to remove soil or spray residues that may negatively affect flavor. (Civantos, 1999; Hermoso et al., 1998).

- ***Fruit Crushing:*** Olives are crushed pit and all to break the cells and release the oil for extraction. The primary machines used to crush olives, are the hammermill and diskmill, which differ in the fineness of paste they create. A finer paste releases more fruit flavor into the oil, but can become homogenized and more difficult to extract the oil. Stone crushers are seldom used in modern olive oil processing because of space required, discontinuous nature of the batch process, and greater exposure of the paste to oxidation (Civantos 1999).

- ***Paste Malaxation:*** The malaxation machine is essentially a jacketed stainless steel tank that slightly warms and slowly mixes the paste. Malaxation reverses the emulsification that occurred in the crushing process, so that large oil droplets are formed, which helps separate the oil from the paste solids and fruitwater. The mixing process optimizes the amount of oil extracted and allows the oil to fully absorb the flavor of the fruit. The paste is slowly stirred for 30 to 60 minutes at a temperature of about 80^o to 86^o F (26.6-30^oC). Temperatures above 86^o F (30^oC) can cause problems such as loss of fruit flavors and can increase bitterness and pungency. The newest trend in the management of olive oil paste is to reduce oxygen exposure. This can be done by either flooding the surface of the mixing tanks with nitrogen or vacuum exclusion of oxygen in special malaxation tanks. Limiting oxygen exposure is believed to reduce enzyme activity that can break down polyphenols, which are antioxidants and major flavor components of olive oil (Alba, 2001; Di Giovacchino et al., 2002; Hermoso et al., 1998).

- ***Paste Separation:*** Modern oil extraction is almost exclusively done with a stainless steel continuous flow vertical centrifuge, called a decanter. Old traditional presses that squeezed stacked up filter mats full of paste are seldom used because that system requires more labor, the cycle is not continuous, and the filter mats can easily become contaminated introducing fermentation and oxidation defects into the oil. Decanters spin the paste at approximately 3,000 rpm and the centrifugal force moves the heavier solid materials to the outside; a lighter water layer is formed in the middle with the lightest oil layer on the inside. In a three-phase system, water is added to get the paste to flow through the decanter, but this washes away some of the flavor and antioxidants, and results in a lower polyphenol content. Two-phase system decanters separate the oil from the solids and fruit-water that exit together. No water needs to be added, so there is better retention of polyphenols. The 2-phase system also produces almost no wastewater compared to the 3-phase system and its waste water has a much lower biological oxygen demand (BOD), but the solid waste is quite wet and more difficult to manage (Alba, 2001; Civantos, 1999; Hermoso et al., 1998).

- ***Oil Cleaning:*** A machine called the vertical centrifuge that spins at 6,000 rpm is used to further separate most of the remaining fruit water and fine solids from the oil before it goes into storage (Alba, 2001).

- ***Oil Storage:*** After processing, oil should be stored in bulk for 1-3 months to further settle out any remaining particulate matter and fruit-water. This eliminates sediment in bottles and oil contact with processing water residues that can lead to off flavors. Premium quality oils should be stored in stainless steel and maintained at a constant temperature of between 45 - 65^{o}F (7.2 – 18.3^{o}C) (Alba, 2001; Hermoso, 1998). Some oils are filtered before bottling.

SENSORY EVALUATION OF OILS

The University of California currently has an olive oil research taste panel that evaluates olive oils according to scientific methodologies set forth in the International Olive Council (IOC) standards. The panel meets twice per month most of the year. One objective in olive oil sensory analysis is to determine if the oils contain defects from improper fruit storage, handling, pest infestation, oil storage, or processing problems. Another objective is to describe the positive characteristics of the oil in relation to its intensity of olive-fruity character. Olive oil should have a fresh fruity olive flavor that is characteristic of the variety or blend of varieties making up the oil. Bitterness and pungency are often present in olive oils, especially when newly made. They are not defects and will mellow as the oils age (Alba et al., 1997; Harwood and Aparicio, 2000; Kiritsakis et al., 1998; Uceda, 2001).

CONCLUSIONS

Small scale olive oil producers in California have been producing high value specialty olive oils for many years. The current California industry is very small, but the domestic market for olive oil is huge and the demand is increasing. Americans certainly have the potential to consume more olive oil like the Europeans. Now, with the new SHD orchard system and automated processing mills, many California growers and processors have the ability to produce excellent quality olive oils at a reduced cost. Orchards configured for over-the-row olive harvest and the use of state-of-the-art, automatic, continuous flow processing equipment are the keys to industry expansion and success. California olive oil producers are now in a position to be competitive in the domestic market with the big volume producers and importers from Europe.

LITERATURE CITED

Alba Mendoza, J. 2001. Chapter 16 Elaboración de Aceite de Oliva Virgen - El Cultivo del Olivo - 4th Edition. Madrid, Spain. Ediciones Mundi-Prensa.

Alba Mendoza, J., J. R. Izquierdo, F, Gutiérrez Rosales. 1997. Aceite de Olive Virgen Análisis Sensorial. Editorial Agrícola Española, S. A. Artes Gráficas COIMOFF, S. A. Madrid, Spain.

Apollo. 2006. Apollo olive oil chosen in the top 10 olive oils of the world by Der Feinschmecker Magazine 2006. http://apollooliveoil.com/

Berenguer, M.J., P.M. Vossen, S.R. Grattan, J.H. Connell, and V. S. Polito. 2006. Tree irrigation levels for optimum chemical and sensory properties of olive oil. HortScience Vol. 41 (2):427-432.

Civantos, L. 1999. Obtención del Aceite de Oliva Virgin – 2nd edición. Madrid, Spain. Editorial Agrícola Española, S. A. – Artes Gráficas COIMOFF, S.A. 306 pages.

DaVero. 1998. Gambero Rosso selects '98 DaVero Dry Creek Estate as the top Tuscan oil. http://www.davero.com/products.php

Di Giovacchino L., S. Sestili, and D. Di Vincenzo. 2002. Influence of olive oil processing on virgen olive oil quality. Eur. J. Lipid Sci. Tech. 104, 587-601

Grattan, S.R., M.J. Berenguer, J.H. Connell, V.S. Polito and P.M. Vossen. 2006. Olive oil production as influenced by different quantities of applied water. Agric. Water Mang. 85:133-140
Gutiérrez Rosales, F., B. Jiménez, A. Ruíz, and M. A. Albi. 1999. Effect of olive ripeness on the oxidative stability of virgin olive oil extracted from the varieties Picual and Hojiblanca and on the different components involved. J. of Food Chem. 47: 121-127.

Harwood, J. L. and R. Aparicio. 2000. Handbook of Olive Oil: Analysis and Properties. Gaitherburg, MD. Aspen Publishers. 620 pp.

Hermoso Fernández, M, J. Gonzáles, M. Uceda, A. García-Ortiz, J. Morales, L. Frías, and A. Fernández. 1998. Elaboración de Aceite de Oliva de Calidad II - Obtención Por El Sistema De Dos Fases. Manual from the Estación de Olivicultura y Elaiotecnia. Finca "Venta del Llano" Mengíbar (Jaén) Spain. Junta de Andalucía Vol. 61/98.

International Olive Oil Council. 2003. The world olive oil market. Olivae No. 97. June 19-25.

Kiritsakis, A. K., E. B. Lenert, W. C. Willet, and R. J. Hernandez. 1998. Olive Oil - from Tree to Table - Second Edition. Trumbull, CT. Food and Nutrition Press, Inc

Krueger, W. H. and P. M. Vossen. 2007. Organic management of common insects and diseases of olive. University of California DANR Organic Olive Production Manual # 3505: 52-57. IN PRESS.

LA County Fair. 2006. Olive oils of the world competition results. http://www.fairplex.com/wine2006/wNewsroom/2006Results.asp

Market Research.Com. 2002. The changing face of edible fats and cooking oils. Packaged Foods, New York. March. (Internet directory of worldwide market research reports).

Pastor, M., Vega, V., Hidalgo, J. C. (2005). Ensayos en plantaciones de olivar superintensivas e intensivas. Vida Rural.

Romero, A., J. Tous, and L. Guerrero. 2005. Caracterización Sensorial del Aceite – Capitulo 15. (Banco de Germoplasma de Cataluña). En: Variedades de olivo en España (Libro II: Variabilidad y selección). Rallo, L.; Barranco, D.; Caballero, J.M.; Del Río, C.; Martín, A.; Tous, J.; Trujillo, I. (Eds.). Junta de Andalucía, MAPA y Ediciones Mundi-Prensa. Madrid.

The Olive Press. 2002. Lunigiana wins the "Best Foreign Oil" Award at the esteemed BIOL Organic Competition in Italy and a "Best Foreign Oil" Award in the ECOLIVA Organic Competition in Spain. http://www.theolivepress.com/store/storedetail.asp?department=Olive+Oils&sku=1012

Tous, J. M., A. Romero, J. Plana, L. Guerrero, I. Diaz, and J. F. Hermoso. 1997. Chemical and sensory characteristics of "Arbequina" olive oil obtained in different growing areas of Spain. Grasas y Aceites, Vol. 48 (6), 415-424.

Tous, J., Romero, A., Plana, J. 2003. Plantaciones Superintensivas en Olivar. Comportamiento de 6 variedades. Agricultura, 815(1): 346-350.

Uceda Ojeda, M. 2001. Chapter 17, La Calidad del Aceite de Oliva - El Cultivo del Olivo - 4th Edition. Madrid, Spain. Ediciones Mundi-Prensa.

Uceda, M. and M. Aguilera. 2005. Caracterización sensorial del aceite. Capitulo 15. (Banco de Germoplasma Mundial de Córdoba). En: Variedades de olivo en España (Libro II: Variabilidad y selección). Rallo, L.; Barranco, D.; Caballero, J.M.; Del Río, C.; Martín, A.; Tous, J.; Trujillo, I. (Eds.). Junta de Andalucía, MAPA y Ediciones Mundi-Prensa. Madrid.

Vossen, P. M., K. Klonsky, and R. L. De Moura. 2001. Sample costs to establish an olive orchard and produce olive oil, Central Coast of California. University of California Davis, Department of Agricultural and Resource Economics Web site, http://coststudies.ucdavis.edu/uploads/cost_return_articles/2001oliveoil.pdf

Vossen, P. M. 2002. Super-high-density olive oil production. OLINT Magazine Special English Edition 1 (Oct.).

Vossen, P. M., J. H. Connell, K. Klonsky, and P. Livingston. 2004. Sample costs to establish a super-high-density olive orchard and produce oil, Sacramento Valley. University of California, Davis, Department of Agricultural and Resource Economics http://coststudies.ucdavis.edu

Vossen, P.M. and A. Devarenne. 2005. California Olive Oil Industry Survey Statistics 2004. UC Cooperative Extension Sonoma County Report. http://cesonoma.ucdavis.edu/hortic/pdf/survey_olive_oil_in_ca_05.pdf

Vossen, P. M., M. J. Berenguer, J. H. Connell, S. Grattan, and V. Polito. 2006. Irrigating oil olives – where quality meets quantity. First Press Newsletter. UC Cooperative Extension, Sonoma County Vol. 1 No. 4.

Vossen, P. M. 2006a. California olive oil industry statistics update. First Press Newsletter. UC Cooperative Extension, Sonoma County Vol. 1 No. 4.

Vossen, P. M. 2006b. Tree spacing for super-high-density planting. Olint Magazine. No. 4 English Edition October.

Vossen, P. M. 2006c. Unpublished conversations with producers, marketers, and tasters of olive oil in California.

Vossen, P. M. and J. H. Connell. 2006. Fertility management for olives. First Press Newsletter. UC Cooperative Extension, Sonoma County Vol. 1 No. 3.

Vossen, P. M. and A. Kicenik Devarenne. 2006. Comparison of mass trapping, barrier film, and spinosad bait for the control of olive fruit fly in small scale orchards and landscapes in coastal California. Proceedings of Olivebioteq, Marsala, Italy. Vol. 2:267-274.

Vossen, P. M. 2007. Site, varieties, and production systems for organic olives. University of California DANR Organic Olive Production Manual # 3505: 3-12. IN PRESS.

Overview of the California Fig Industry and New Interest in Varieties for Fresh Fruit

Ed Stover and Malli Aradhya
USDA, ARS National Clonal Germplasm Repository, One Shields Ave., University of California, Davis, California 95616, U.S.A.

Carlos H. Crisosto and Louise Ferguson
Dept. of Plant Sciences, One Shields Ave., University of California, Davis, California 95616, U.S.A.

Introduction

Cultivated figs (*Ficus carica* L.), have a long history of human use, reportedly becoming established across the Mediterranean region around 6000 years ago (Ferguson et al., 1990). The fig is well-adapted to drought and high temperatures and is widely planted in home gardens throughout the Mediterranean region (and similar climates) and is commercially produced in scales ranging from very small to very large farm operations. Worldwide, figs are harvested from 427,000 HA, producing over 1 million MT per year (FAO, 2006). Turkey is the largest fig producer at ~26% of the world's figs. The top six producing countries (Turkey, Egypt, Iran, Greece, Algeria and Morocco) account for ~70% of world annual production. In 2005, the United States ranked eighth with 4% of global fig production. Fourteen US states report commercial fig production. However, California produces 98% of the US crop, on 5,100 HA, but with a yield per HA three times the global average. California production is largely concentrated in the San Joaquin Valley, where the hot dry summer is ideal for both fig production and the drying of figs under ambient conditions.

The fig tree

Fig trees are deciduous, fast-growing, and spreading in habit. Plants typically grow into single-trunked trees with little training. Branches have a pithy interior and the wood is low in density and breaks easily. Latex is produced from all broken plant structures, and is a pronounced skin irritant. Mature tree height varies by variety and typically ranges from 3 to 10 meters. Fig trees can be pruned aggressively and remain productive since most fruit is on current season's growth. Some growers are now producing figs on small plants trellised like grapevines.

Structure of the fig fruit

The fig "fruit" is a hollow shell of receptacle tissue enclosing hundreds of individual drupelets which develop from the individual female flowers lining the receptacle wall, and has a small scale-lined opening (called the ostiole or eye) at the distal end. This composite fruit is called a "syconium" (reviewed in Condit, 1947). The initial prosyconium are so small that figs were once considered to bear fruit without ever forming flowers. The mature fruit of the edible fig has a somewhat tough skin (often with crack marks), a whitish interior rind, and a sweet gelatinous pulp comprised of the individual ripe drupelets. The seeds within the drupelets range from virtually non-existent to subtly crunchy.

Fig pollination biology and its genetic basis

The fig has an interesting and distinctive pollination biology which is important in commercial production. Wild figs (known as caprifigs) produce male and female flowers within the syconium. Fruiting cultivars produce functional female flowers with abortive hermaphroditic flowers ringing the ostiole (Beck and Lord, 1988), but vary in their need for pollination.

The female flowers in edible figs are long-styled and produce a much more succulent fruitlet, in contrast to female flowers in the short-styled monoecious wild-type figs. Storey (1975) suggests that a mutation in the wild fig gave rise to the long-styled pistils and succulent fruitlet of the edible fig. Mutation in a tightly-linked gene or a pleiotropic effect of the same gene results in suppression of the androecium in the edible fig. Some monoecious figs are considered edible and have a more succulent fruitlet than typical for these types (e.g. 'Croisic'). We do not know of any studies which investigate the anatomical or genetic factors which result in these so-called edible caprifigs.

Four types of figs are distinguished by their cropping/pollination characteristics. The type known as "common figs" are edible functionally female figs which require no pollination to set a commercial crop. For figs, the term "persistent" is preferred over "parthenocarpic", since the fig is not a true fruit. The other two types of edible fig require pollination to set the main crop of figs. These non-persistent types are termed "cauducous" and are classed as Smyrna types (e.g. 'Calimyrna') and San Pedro types (e.g. 'King'). The San Pedro types are distinguished by setting a persistent crop on previous season growth, but require pollination to set the main crop on current season's growth.

The 4th type, known as caprifigs (goat figs), are those with both male and female flowers, and include the wild-type figs. Selected caprifigs, with desirable qualities, are grown for pollination of commercial plantings of cauducous figs. Fig pollen is carried by a wasp (*Blastophaga psenes* L.), which has coevolved with the fig (Kjellberg et al., 1987). An important aspect of this coevolution is the protogynous nature of the caprifig. The female flowers are receptive 6-8 weeks before anthers mature in the same syconium (Condit, 1932) permitting wasps to enter, pollinate and oviposit in syconia which will have mature pollen as the next wasp generation emerges.

The wasps cannot mature in edible figs, but complete their life-cycle in caprifigs. Commercially, caprifig trees are maintained in separate orchards so that pollen flow to edible figs can be controlled. Mature caprifig fruits are cut and hung in bags or baskets in trees of edible figs requiring pollination. Typically they are supplied three times in California fig production, at regular intervals in May-June. The goal is to have only one wasp enter each fig since excessive pollination increases fruit splitting and internal defects caused by microorganisms are increased with the entry of multiple wasps.

Fig cultivars

Naming of fig cultivars is recorded as early as the 4th century B.C.E, with 29 varieties listed by Pliny in the first century A.C.E. (Bostock and Riley, 1855). After eliminating suspected synonyms, Condit (1955) described 607 named fruit-producing cultivars. The California fig industry is largely based on five cultivars: Calimyrna (Sari Lop), Adriatic, Mission, Brown Turkey, and Kadota (California Fig Advisory Board, 2006; California Fresh Fig Growers Association, 2006). All of these except 'Brown Turkey' are suitable for drying and all are enjoyable as fresh fruit. 'Brown Turkey' is a common-type fig which is productive and has very large fruit, but is too low in sugar to make a quality dried product. The 'Calimyrna', which is known as 'Sari Lop' or 'Lop Injer' in Turkey, is the most important drying fig in the world and requires pollination to produce fruit.

Of the cultivars described by Condit (1955), 78% are common-types, less than 4% are San Pedro-types, and the remaining 18% are Smyrna-types. Cultivars also vary in such traits as leaf morphology, plant vigor, fruit external and internal color, fruit flavor/Brix/titratable acidity, seed characteristics, shape of fruit, skin thickness, ostiole diameter, and duration of fruit production.

Breba crop vs. main crop

Brebas are the first figs of the season, setting on wood from the previous year, and typically mature in June in the Central Valley of California. While San Pedro types are in part defined by the setting of a breba crop, some common figs will also produce brebas. Some cultivars are grown because of their tendency to produce brebas, which tend to be larger than main crop figs, are relatively scarce on the market and tend to get a high price as fresh fruit. The main crop is produced on the current season's wood, maturing fruit from August through November (in Winters, Calif.) or even later in a warm year. Achievement of maturity in main crop fig fruits on a single tree is sequential, beginning with development of fruits at the base of the current year's growth and progressing toward the most distal fruits. This makes it necessary to harvest repeatedly in production of fresh fruits (Chessa, 1997), while figs for drying are typically collected from the ground in a single harvest for main crop figs (Obenauf et al., 1978). Brebas achieve maturity in a very brief period in an orchard, are very few in number compared to main crop figs in most varieties, are much larger fruit than main crop figs of the same variety, and tend to be less flavorful than corresponding main crop figs.

California cultural practices

New fig plantations are typically established after 12-15 months in the nursery and will set some fruit in the following year (Morton, 1987), but generally reach good commercial production in 3-5 years. Fig is extremely drought–tolerant once established, but needs regular watering during establishment and achieves greater yields where irrigated. Commercial California orchards are routinely irrigated: water supply is reduced in the weeks prior to maturity for dried-fruit production but is maintained for fresh production. Fig thrives on soils ranging from light sand to heavy clay or limestone (Morton, 1987). Fig orchards do not require regular fertilization unless grown on sand, and excessive application will encourage plant growth at the expense of fruit production. No more than 0.2-0.5 kg of N should be applied per tree per year, with split applications from early spring through July (Morton, 1987). Nitrogen is the only nutrient which is regularly applied to fig orchards.

Orchards for dried fig production in California are typically planted at wide spacings (6 to 12 m between trees), receive pruning to sustain adequate annual growth, and figs are harvested from the manicured orchard floor after abscission (Ferguson et al., 1990). Figs for fresh fruit production in California are often spaced more closely and are topped to permit harvest with minimal ladder-work, since each tree will require many passages to harvest the fruit which is mature. In pruning figs, special care must be taken if breba production is important, since these fruit grow on the previous season's wood.

Figs in California have few routinely serious pests or diseases, and even commercial orchards rarely receive pesticide sprays. Arthropod pests are sporadically important and include dried fruit pests like the Coleopteran *Carpophillus hemipterous* and Lepidopteran *Ephestia figulilella* (reviewed in Ferguson et al., 1990). *Alternaria* and *Fusarium* are especially noteworthy for producing internal fruit rots and are the primary fungal concerns in California fig production, while other diseases may be important in some orchards in individual years (reviewed in Ferguson et al., 1990). Worldwide, Fig Mosaic Disease (FMD) is a concern, producing typical mosaic virus symptoms of yellow rings on leaves and sometimes symptoms on fruit. Stunting of trees and reduced productivity are associated with severe foliar symptoms (California fig growers, pers.comm.).

Dried fig products

Dried fig is an excellent product which is widely appreciated, nutritious and long-storing. Typically greater than 95% of California figs has been utilized as a dried product (Economic Research Service, 2004). California dried figs are harvested after falling from the trees. They are then washed, sampled for both internal and external defects and are aggressively graded to insure the consumer receives a high quality product. Much of the cosmetically defective fruit are used to produce fig paste which is used in baked goods and confections. Yellow figs like 'Calimyrna' and 'Kadota' are often treated with sulfur dioxide to maintain a brighter appearance and the final product ranges from gold to amber in color. The only black fig with significant dried production in California is the 'Mission' which produces a deep black dried product. California figs are typically partially hydrated to produce a more moist and plump product than the typical imported dried fig, and are often treated with sorbates to inhibit growth of microorganisms (Valley Fig Growers, 2006). The long-storage and ease of handling dried figs has made them important in commerce, but also increases global competition in marketing this product. Average grower price for California figs ranged from $272 to $475 per ton from 2000 to 2003 with yields of slightly less than 10 tons/ha (FAO, 2006).

Fresh fig production

Consumer demand for premium produce has increased the interest in commercial fresh fig production in California. In the last five years, total California production of processed fig has been fairly constant, but fresh fig production has doubled, so that in 2005, fresh figs represented more than 9% of California commercial production (NASS, 2006). Consumer prices for fresh figs are quite high and appear to be comparable to those of other highly perishable soft fruits, such as raspberries. Although data are not available, it seems likely that these high prices reflect considerably greater returns to the grower successfully marketing fresh figs.

Orchards for fresh production are managed differently from drying fig orchards, with severe topping for pedestrian harvests and irrigation throughout the harvest season. The other significant difference is that most breba fruit that are marketed commercially are sold as fresh fruit. The relatively low production of breba fruit in most varieties make them uneconomic to collect for dried use.

The increase in fresh fig sales has been largely based on standard California fig varieties. However, increased interest in fresh production has stimulated exploration of other varieties for fresh marketing.

Investigating new varieties for fresh fig production
The National Clonal Germplasm Repository (NCGR) in Davis, California houses the U.S. collections of most of the Mediterranean-adapted fruit and nut crops. The NCGR fig collection currently includes: 78 named fruiting cultivars, 44 regional selections from diverse areas of the world, 40 advanced selections from plant breeders (mainly from the UC Riverside breeding program) , 28 caprifigs, and a small number of species and hybrids. The named cultivars in the NCGR collection represent a fair cross-section of figs from major old-world growing areas and represent the largest collection in North America. While the majority of current commercial cultivars feature flavors of honey or caramel, some NCGR accessions have bright fruity flavors, reminiscent of berries or citrus, as well as noticeable acidity to complement sweetness. Because, there is new interest in developing commercial fresh fig production, we are conducting evaluations on many accessions, using funds provided by the California fig industry. Information is provided below for our 2005 evaluations, as data are not yet analyzed from 2006.

For some traits, the entire bearing collection of 137 edible accessions was screened, while for most traits, data was collected on a core group of 26 accessions. Considerable variation was observed for time of maturity. Breba production was markedly greater in 'King' than in any other genotype in the core group, with almost 3X more fruit per branch than the next most breba-productive variety. 'King' had almost 8x higher breba production than the commercial standards 'Mission', 'Kadota', or 'Brown Turkey'. Earliness of ripening in the large collection was most pronounced in 'Yellow Neches', 'Orphan', and 'Santa Cruz Dark' with 3X as many ripe fruit per tree in early August as the earliest commercial standard, 'Brown Turkey'. Several commercial standards scored among the varieties with greatest late season production (~200 fruit per tree ripe after mid-Sept with 'Brown Turkey' and 'Mission' comparing favorably with 'Zidi', 'Panachee', and 'Ischia Black' among others. Across the entire collection, 'Verdal Longue' was especially notable for having many fruit late in the season and still had many unripe fruit in October. 'Vernino', 'Alma', 'Ischia White', and '143-38' were also notable in still having many ripe and some unripe in mid October.

For fruit quality and postharvest evaluations, fruit from 26 varieties were collected on 18 August 2005, selecting tree ripe fruit (neck sagging slightly) and commercially ripe fruit (well colored, but not sagging). The firmest fruits were those of 'Snowden'. The fruits of 'Zidi' were the largest at 58-59 grams, with 'Brown Turkey' second at 50-57 grams. Soluble solids (SSC) varied widely. 'Orphan' and 'Brown Turkey' were the lowest in SSC (13-16%), both at commercial maturity and when tree-ripe. 'Adriatic', 'Golden Celeste', 'St. Jean', 'White Texas

Everbearing', '135-15s', and 'Zidi' where in the highest SSC category (17-26%). Hative de Argentile and Violette de Bordeaux had the highest titratable acidity.

Fresh fig quality is greatest at full ripeness but such soft figs are especially sensitive to damage (Chessa, 1997) and have very poor market life. Therefore, the balance between quality and even modest shelf-life demands harvest at early ripeness (good color) in fresh-figs for commercial sale. The data we collected permitted assessment of fruit changes as they progress from commercially ripe to tree-ripe. Fruit weight only increased by 9% during this period, while color coverage increased by 14%, SSC increased by 31%, and TA decreased by 37%. A 30% increase in sugar, combined with obvious reduction in fruit latex and possibly increased aroma-volatiles as fruit mature, help explain the superiority of tree-ripe fruit

Fruit varied widely in their ability to maintain quality postharvest. 'Brown Turkey' was among the best and had 90% sound fruit after storage of commercially-ripe fruit at 0°C for seven days, and 70% of fruit remained sound after an additional 3 days at 20°C. '152-4s', 'Adriatic', 'Calimyrna', 'Dauphine', 'Panachee', 'UCR 276-14', 'Violette de Bordeaux', and 'Zidi' were also among the best for postharvest storage. Several other cultivars ranked just a bit behind these, while others held up very poorly. (There are some excellent genotypes for fig paste)

Ethylene and respiration levels that were measured indicate that the climacteric occurs before commercial maturity. This may have significant implications for postharvest handling, as this indicates that fruit are essentially on the down-slope of senescence when they are coloring

Into the future

As a complement to the rich pleasures of dried figs and their products, it is likely that fresh fig sales will expand in the U.S and around the world. This would be greatly assisted by significant advances in post-harvest handling and development of more diverse varieties. Based on our experience with naïve consumers, the potential customer base for fresh figs is very large. Visitors to the NCGR are especially delighted by the bright fruity flavors, reminiscent of berries or citrus, of some fresh fig varieties. An interesting comment regarding potential fig appreciation is that of the prophet Mohammed indicating, "If I could wish a fruit brought to paradise it would certainly be the fig" (Condit, 1947). It is strange to think that this esteemed fruit is virtually unknown to most U.S. consumers, except as a brown paste inside distinctive fig cookies.

Our investigations will likely continue over the next several years, with results ultimately published on our website. We are also committed to acquiring additional material and are very interested in learning of such opportunities. Recently we have added 50 additional accessions to our collection. It is our policy to distribute plant material, free of charge, to research interests around the world (see our website http://www.ars-grin.gov/dav/).

Literature cited

Beck, N.G. and E.M. Lord. 1988. Breeding system in Ficus carica, the common fig. I. Floral diversity. Am. J. Bot. 75:1904-1912.

Bostock, J. and H.T. Riley (trans.). 1855. Pliny the Elder: The Natural History, Book 23, Chapter 63. Taylor and Francis, London.

Chessa, I. 1997. Fig. In: S. Mitra (ed.). Postharvest physiology and storage of tropical and subtropical fruits. CAB International, Wallingford, UK, pp. 245-268.

California Fig Advisory Board. 2006. Varietal info. <http://www.californiafigs.com/about/index.html> Aug. 2006.

California Fresh Fig Growers Association. 2006. Seasons and varieties. <http://www.calfreshfigs.com/seasons.html> Aug. 2006.

Condit, I.J. 1932. The structure and development of flowers in *Ficus carica* L. Hilgardia 6:443-481.

Condit, I.J. 1947. *The Fig.* Waltham, Mass, USA.

Condit, I.J. 1955. Fig varieties: a monograph. Hilgardia 23:323-538.

De Candolle, A. 1886. Origin of cultivated plants (reprint of 2nd edition 1967). 468 pp. Hafner Publishing Co., New York

Economic Research Service. 2004. Commodity highlight: figs. <http://www.ers.usda.gov/Briefing/FruitAndTreeNuts/fruitnutpdf/Figs.pdf> Dec. 2006.

FAO. 2006. FAOSTAT agricultural data. < http://faostat.fao.org/site/408/default.aspx > Dec. 2006.

Ferguson, L., T. J., Michailides and H.H Shorey. 1990. The California fig industry. Hort. Rev. 12:409-490

Kjellberg, F., P.H. Gouyon, M. Ibrahim, M. Raymond and G. Valdeyron. 1987. The stability of the symbiosis between dioecious figs and their pollinators: a study of *Ficus carica* L. and *Blastophaga psenes* L. Evolution 41:693-704.

Morton, J. 1987. Fig. p. 47-50. In: Fruits of warm climates. Julia F. Morton, Miami, FL.

NASS. 2006. Noncitrus fruits and nuts: 2005 summary. <http://usda.mannlib.cornell.edu/usda/nass/NoncFruiNu//2000s/2006/NoncFruiNu-07-06-2006_final.pdf> Dec. 2006.

Obenauf, G., M. Gerdts, G. Leavitt and J. Crane. 1978. Commercial dried fig production. University of California. DANR Sci. Leaflet 21051.

Storey, W.B. 1975. Figs. p. 568-588. In: J. Janick and J.N. Moore (eds.), Advances in fruit breeding. Purdue University Press, West Lafayette, Indiana.

Valley Fig Growers. 2006. Growing and processing. <http://www.valleyfig.com/c_figs/growing.htm> Dec. 2006.

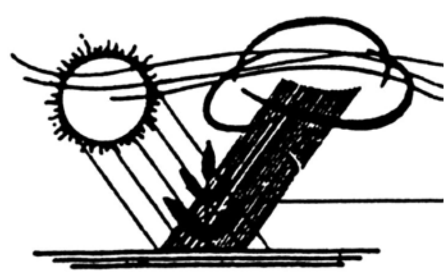
Session VI

Energy Conservation Strategies

Session Chairs:

William Horwath, LAWR, UC Davis

Bruce Roberts, CSU Fresno



The California Climate Action Registry's Livestock Manure Management Project Protocol

Mike McCormick, Policy Director, California Climate Action Registry

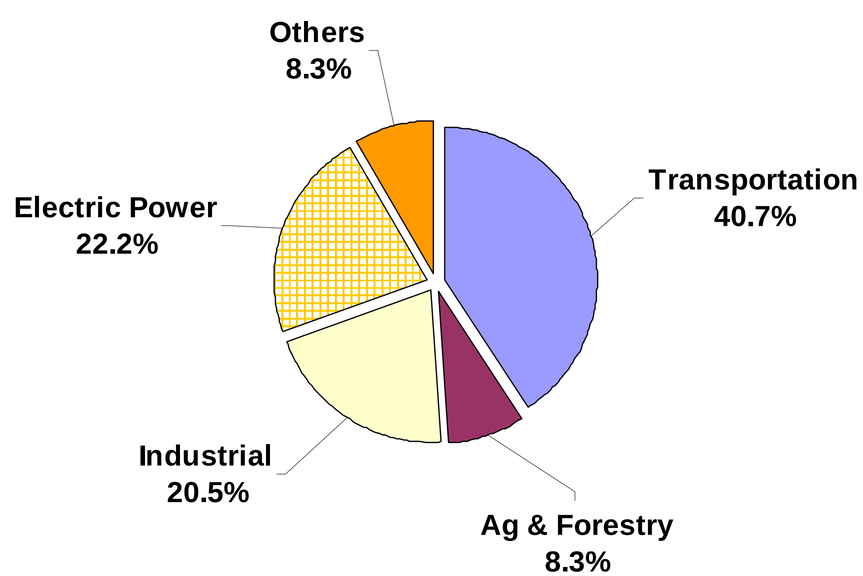
515 S Flower St, Suite 1640, Los Angeles, CA 90071
(Phone) 213.891.1444, (Fax) 213.623.6716
mike@climateregistry.org

To promote the positive contribution by the agriculture community to reduce greenhouse gas (GHG) emissions, the California Climate Action Registry is developing protocols that provide guidance to report and certify GHG reductions. We will initially focus on projects that capture and destroy methane emissions from livestock operations through the installation of an anaerobic digester. The users of the protocol will include dairy cattle, beef cattle, and swine farmers. This paper provides information on the Registry, our livestock manure management project protocol, and its development process.

Our objective in producing a livestock manure management project protocol is twofold: (1) facilitate activities that reduce GHG emissions by dairy, swine, and beef cattle farmers; and (2) assist livestock owners take advantage of opportunities in the emerging GHG, or carbon-offset, market.

Although agriculture contributes a relatively small amount (~8%) to overall GHG emissions in California, several low cost, near term opportunities exist to reduce GHG emissions – and methane capture chief among them.

Sources of California's 2004 GHG Emissions, by End-Use Sector (Includes electricity imports and excludes international bunker fuels)



Source: California Energy Commission

The Registry will also explore developing protocols for other project types, such as improving the efficient use of fertilizers to reduce nitrous oxide emissions from soils, increasing the amount of carbon stored in soils through improved soil management, and boosting the use of biogas and biomass resources for renewable electricity generation.

What is the California Climate Action Registry?

The Registry was established by the California Legislature in 2000 as a non-profit, public/private partnership to serve as a voluntary GHG registry. We run a GHG reporting program, which companies and organizations elect to join; as a member they agree to account for and certify their emissions according to our protocols.

The Registry's purpose is to help our members reduce their GHG footprint. Our high quality, standardized emissions reporting and certification protocols support actions to measure, monitor, and reduce GHGs. The State has also charged the Registry with developing procedures for reporting and certifying GHG emissions reductions.[11]

What is a GHG Emission Reduction Project?

A GHG project is a specific activity (or set of activities) intended to reduce GHG emissions, increase the storage of carbon, or enhance GHG removals from the atmosphere. For the purposes of the Registry's livestock manure management project protocol, we define the reduction activity as the installation of a digester that captures and combusts methane gas.

What is the Registry's Manure Management Project Protocol?

Project protocols provide guidance to assess the impact of an emission reduction activity and provide steps to credibly, transparently, and practically account for, report, and verify the resulting GHG reductions. Ultimately, project protocols enable project developers and GHG programs to demonstrate that the effects of the emission reduction activity are real, surplus, and verifiable.

The Registry's manure management project protocol will be an emissions accounting and reporting standard to support GHG reduction activities at livestock operations. It will be the tool used by project developers to register their emissions reductions with the Registry. The document will have both policy-related guidance (e.g., defining project boundaries) and technical guidance (e.g., selecting calculation procedures). The protocol will have the following components, which are necessary to demonstrate credible GHG reductions:

- Define the GHG reduction project
- Establish the accounting boundary
- Determine additionality
- Characterize the baseline
- Identify quantification methods to estimate baseline and project GHG emissions
- Calculate GHG reductions
- Verify project performance
- Other issues

What is a Credible GHG Reduction?

Several important principles underpin creating quality GHG reductions – the highest being environmental integrity, which is achieved by satisfying the "surplus"/"additionality" criterion and the "real" criterion. Other significant principles include practicality, transparency,

[11] CA Health and Safety Code Section 42823(c)

and consistency. The Registry's approach to determining credible GHG reductions is consistent with EPA Climate Leaders, the Oregon Climate Trust, and other offset providers.

There is little doubt that the GHG reductions registered with the Registry will be treated as tradable commodities and sold by project developers to buyers that intend to "offset" their emissions. In order for this transaction to have validity, the "reduction credit" must actually represent what it claims to represent. That is, the project must result in emissions to the atmospheric that are actually lower than they would have been otherwise; the emissions reductions must exceed business-as-usual. In other words, the GHG reductions must be surplus or additional to business-as-usual emissions.

The Registry's protocol will satisfy this requirement by developing a top-down standard that uses a program-wide performance threshold to determine surplus (i.e., additional) reductions. To produce surplus/additional reductions, the project must meet or exceed an established threshold. The rationale is that the threshold represents better than business-as-usual emissions; if the project meets or exceeds the threshold, then it will exceed what would happen under business-as-usual. The threshold is defined on an upfront basis, by the Registry. We use a technology-specific threshold: an anaerobic digester.

The Registry will also apply a regulatory screen to make certain that projects are not developed for the sake of regulatory compliance. This means if a regulation forced a livestock operator to install a digester, then the use of that digester is considered business-as-usual.

Moreover, the GHG reductions must be calculable. The procedure to calculate baseline and project emissions must lead to values that meet an acceptable level of certainty – i.e., the reductions must be real. Usually, that level of certainty is equivalent to corporate-wide inventory boundaries. The Registry's livestock manure management project protocol will ensure that all reductions are real by rewarding only those activities for which there are calculation methodologies that yield emissions values with high level of certainty.

We also believe using the Registry's protocol will facilitate consistent and transparent reporting. Additionally, the Registry anticipates that this type of protocol (with program-specific rules and procedures set from the top-down and applicable to all projects) will be considered a practical approach by developers.

Will the Project Protocol Cover Emissions Reductions from Using Biogas?

A key issue when defining the GHG reduction activity is the concept of "scope," which (in the realm of GHG accounting) is used to delineate direct and indirect emissions sources. Direct emissions occur from sources that are owned or controlled by the reporting entity. Indirect emissions generally refer to emissions that occur because of one entity's actions but are ultimately produced from sources owned or controlled by another entity.

In the case of the Registry's livestock manure management protocol, installing anaerobic digesters can (in some instances) reduce both direct and indirect emissions. In addition to reducing direct emissions from storage ponds and lagoons (which are owned and controlled by the livestock owner), digesters can be a part of a system that generates – renewable – electricity and reduces emissions from grid-delivered, fossil fuel-produced power. Additionally, the biogas could also be used in place of other fossil-based fuels to power on-site backup generators or pumping systems, for instance.

Displacing grid-delivered energy is classified as an indirect emissions reduction activity because the change in GHGs actually occurs from sources owned and controlled by the power producer, even though the project developer might reduce his electricity consumption. Capturing methane from a lagoon and turning it into electricity to displace grid-delivered power is actually defined as *two project activities*: 1) the direct emissions reduction activity and 2) the indirect activity.

In a separate development process, the Registry plans to establish a project protocol for all grid-delivered renewable energy projects, which would also apply to indirect emissions reductions from using biogas from anaerobic digesters.

Therefore, while the Registry fully supports increased biogas and biomass use to decarbonize the power sector, the protocol will only cover GHG emissions reductions associated with direct sources (i.e., those owned and controlled by the livestock owner/operator). This includes

- Capturing and combusting methane that would otherwise escape from waste storage, or
- Using the captured biogas to fuel on-site equipment.

When will the Protocol be Ready for Use?

To initiate the protocol development process, the Registry conducted a scoping meeting in the spring of 2006. This meeting evaluated several types of GHG reduction options for the agriculture sector; an outcome was for the Registry to focus on the development of a protocol for methane capture.

Since then we have formed a protocol development workgroup, and have conducted two workgroup meetings. Its objective is to support the Registry's effort by providing informed advice on GHG accounting and reporting matters for this sector.

The Registry intends to have a draft livestock manure management project protocol available for public review in the spring of 2007. We will announce when it is ready on our website, http://www.climateregistry.org/PROTOCOLS/PIP/.

On-Farm Experience with Biofuels

John Diener, Owner, Red Rock Ranch
15086 Oakland Avenue, Five Points, CA 93624
Phone (559) 884-2840, FAX (559) 884-2359, john@rrrinc.net

Abstract

California biofuel development is an intriguing subject for farmers, energy producers, and consumers - all can benefit from the potential found in creating energy from crops. These crops can also contribute to soil and water conservation and reclamation, adding to their intrinsic value. Red Rock Ranch has set a goal of finding profitable crops that rejuvenate and utilize soil components and water supply, while figuring in to a biofuel equation. Assisted greatly by Dr. Gary Banuelos, USDA/ARS, we have had success in growing canola, which removes selenium from the ground and utilizes our reclaimed irrigation water from tiled soils. Our experience with sugar beets, a durable and energy-rich crop, has also been positive. However, we have found that much research needs to be done in cellulosic degradation of raw materials, with the goal being complete usage of product with no resulting by-product. Funding towards this research is absolutely crucial. A fair and sensible relationship to the electricity grid is also imperative to sustainable success. California biofuel development will require great changes in how land is farmed, products are processed and energy is distributed in order to make it profitable. Finally, as in many agriculture-related issues, it must be understood that the potential as well as the challenges for biofuels are different in California than the rest of the United States.

Outline of Mr. Diener's Presentation

Welcome to Red Rock Ranch

A. Location – Five Points, California; a part of Westlands Water District.
B. History of Crops Grown and Water/Soil Management System Development.
C. Agronomic Goals and Philosophies - profitable progress toward restoration of soil and water quality as well as energy self-reliance.

Canola

A. Soil benefits and practical crop production.
B. How canola fits into the rotation system.
C. Possible uses for cattle feed and biodiesel production.
D. Conversion rates of canola oil to biodiesel.

Sugar Beets

A. Energy-packed crop, grows efficiently.
B. Conversion of sugar beets to ethanol:
   1. Field harvested beets at a sugar content of 15% sugar equals 300 lbs of sugar per ton of beets.
   2. Using degree Brix (a measure of soluble solids) as equal to percent sugar the example of 15% beets would be 15 degrees Brix. To convert to alcohol, multiply by .55 and create 8.25% alcohol. Multiply 8.25% X 2,000 lbs = 165 lbs of alcohol. Then, 165 lbs of alcohol divided by 7.23 lbs/gal of alcohol = 22.8 gals of alcohol per ton. If 40 tons of beets per acre are grown, theoretical production equals 40 ton X 22.8 gals or 912 gals ethanol per acre.

Research, Funding, Politics, Engagement

A. What needs to happen in order for biofuels to progress in California.
B. Cellulosic research.
C. Access to the electricity grid – reasonable credits and debits system.

Demonstrating Financial Benefit as Catalyst for Adoption of Conservation Technologies and Practices on California Dairy Farms

Allen Dusault
Program Director, Sustainable Conservation
98 Battery Street, San Francisco, CA 94111
Phone (415) 977-0380, FAX (415) 977-0381, adusault@suscon.org

Introduction

The concept of farm sustainability is now ubiquitous as environmental impacts from agriculture and related opportunities are increasingly debated. However, if the agricultural sector is to be viable in context of the global free market, sustainability must be premised not just on environmental factors but also financial considerations. My organization has initiated a program that promotes an innovative model of sustainability. The program has initially targeted California dairies (and is now expanding to other commodities) and supports environmentally beneficial technologies and practices that provide economic benefit. While our focus is on the San Joaquin Valley area (home to about 1,600 dairies), a number of the technologies we promote have widespread applicability to dairies in other regions of the United States. Hence, in addition to pioneering these approaches on California dairies, we are also communicating the benefits of these practices to dairies around the U.S. Three examples are highlighted below focusing on resource conserving technologies including a land application technique suitable for distributing nutrients via flood irrigation (common in the west), manure capture and processing technologies and reduced input tillage practices that have lower energy use and reduce air quality impacts.

Industry Profile

California's dairy industry is the largest in the nation. One out of every five gallons of milk produced in the U.S. comes from California (CDFA, 2005). The Central Valley region of California, encompassing the Sacramento and San Joaquin Valley and the Tulare Lake Basin, is home to over 700,000 cows – each producing about 120 pounds of liquid and solid waste per day (CDQAP, 2004). It is estimated that this amounts to about 2 million dry tons of manure per year (Krich, 2005). Most of the waste generated by dairies is put into storage lagoons and typically ends up being applied to cropland. Typical application rates have resulted in high levels of salts and nutrients in ground and surface waters. Some of this contaminated water potentially drains to the Bay Delta, a water supply source for millions of people.

Most of California dairies are large, averaging over 800 lactating cows (CDFA, 2005). They also tend to use flush systems to move manure to storage "ponds" or lagoons, as they are referred to in the local vernacular. That requires a lot of water and large amount land application areas to uptake the nutrients. Not all dairies have adequate land area and many of those that do are situated over permeable soils with shallow ground water tables (CRWQCB, 2006). Watershed studies for Tulare Lake and the San Joaquin River Basins have found that nearly 600 square miles of groundwater are contaminated with high levels of nitrates, and nearly 3000 square miles have elevated salinity levels (CRWQCB, 2006). High nitrate and salt concentrations have resulted in the closure of drinking water supply wells in some areas. The Water Quality Control Plan for the San Joaquin River and Tulare Lake Basins identifies salts and nutrients from animal operations (primarily dairies) as major water quality concerns (CRWQCB, 2006). New regulatory initiatives will make it much harder for dairies to continue current practices and new solutions must be developed that address groundwater impacts from the leaching, particularly of nitrate and salts.

Program Objectives

The objective of the program has been to identify and promote the adoption of high-impact technologies that help dairy producers conserve resources and reduce energy use while being cost-effective/profitable and practical from a farm management perspective.

Our specific goals were to:

1. Identify, demonstrate, and quantify the effectiveness of promising technologies and practices in providing both economic and conservation benefits to the dairy industry.
2. Develop promotional and outreach materials that document the economic advantages of targeted practices/technologies while identifying limitations.
3. Implement a communication/marketing plan that results in a significant number of dairymen adopting suitable technologies and practices.

Technologies most aggressively promoted are those with the following characteristic:

1. They have been used successfully on representative dairy farms in the region and are cost-effective and practical from a farm management perspective.
2. They result in enhanced capture and control of dairy manure nutrients, reduce energy consumption, air pollution and/or groundwater contamination.
3. They are available for adoption by dairy producers in the region and provide a reasonable return on investment (payback of less than 5 years).

Methods Used to Support Technology Promotion/Transfer

- State and Federal grant funds to catalyze adoption of targeted technologies/practices;
- Collaboration with dairy producer organizations, farm industry representatives, cooperative extension, NRCS and university researchers on implementation;
- Workshops putting dairy producers in direct contact with equipment suppliers;
- On farm field days allowing producers to hear and learn from early adopter dairymen about how well the technologies work in practice and their limitations;
- Articles written for dairy producer publications that serve as a credible source of information on innovative practices;
- Presentations at industry conferences targeting dairy producers and advisors/consultants;
- Collaboration with dairy industry leaders on a nationally distributed report highlighting financially successful technologies and practices.

Description and Economic Advantages of Supported Technologies and Practices

1) Synchronized Rate Nutrient Application in conjunction with Optimization Modeling of Manure Nitrogen Availability:

Dairies in the Central Valley typically have freestall barns (areas where the cows spend a majority of their time when not in the milking parlor) and use recycled water using a 'flush' system. Water recycled from the manure ponds or from milking parlor cleaning, flows down the freestall floor lanes and transports manure liquids and solids to the "lagoon" for storage. Manure liquids stored in these large ponds are used to irrigate the crop and provide nutrients for the crops that are grown. Most dairies in California's San Joaquin Valley do not have pastureland but do grow corn for silage and winter forage crops. However, until recently, there was no systematic method to accurately land apply manure nutrients based on crop needs. That has resulted in potentially widespread over application of manure liquids, occasional yield penalties from excess nitrogen build up and apparent groundwater impacts from nitrate leaching to the saturated zone.

Synchronized rate nutrient application is a technology developed by University of California Cooperative Extension (UCCE) as a means to distribute liquid dairy lagoon nutrients to fields at rates appropriate for crop uptake and at times that maximize crop uptake of nitrogen and minimize leaching of nitrogen to groundwater. Using field nitrogen tests for rapid assessment of lagoon nitrogen concentrations, flow meters, and irrigation systems that distribute lagoon water in conjunction with irrigation water to fields (typically via flood irrigation; 3), and a spreadsheet program that determines appropriate application rates based on the crop's stage of growth, producers have reduced groundwater nitrate concentrations by over 50%, according to UCCE field research. They have also reduced or eliminated commercial nitrogen use.

Economic analysis of this practice was conducted by interviewing producers using this technique. They reported an average cost savings of approximately $80 per acre in avoided fertilizer expenses, which translated into annual savings in the range of $40,000 to $50,000. The actual savings associated with adopting this practice is expected to vary from farm to farm and is largely dependant on the farm size and typical fertilizer expenses. However, it is important to note that commercial fertilizer prices have been increasing since 2001, partly due to increased cost of natural gas, a key ingredient in fertilizer manufacturing that can account for up to 90% of the cost of commercial nitrogen production. Reduction or elimination of commercial nitrogen use on dairies has both commensurate reduction in upstream energy consumption and fuel savings from avoided on farm nitrogen fertilizer application.

2) High-Efficiency Solid-Liquid Separation Systems:

Solid separation systems can be installed to remove solids prior to storing flush water in manure ponds. According to the USDA-NRCS practice standards, while single-stage solid-liquid separation systems remove approximately 10-20% of the solids in flush water, high efficiency solid-liquid separation systems achieve solids removal rates as high as 85%. Double screen systems are now being used in California with efficiencies that approach the upper limit. They typically do not require additional power to operate (other than the pumps), are relatively simple in design and have the ability to prevent build up off solids in holding ponds and storage lagoons. Separated solids can be used for bedding or composted and sold as an organic soil amendment.

Installing a high-efficiency solid-liquid separation system to treat flush water prior to lagoon storage has several significant advantages: 1) solids accumulation in the lagoon, which reduces available storage space, is minimized; 2) taking out the solids makes it much easier to move lagoon liquids long distance through irrigation lines, and; 3) it is possible to distribute nutrients more evenly across long fields where irrigation water flows from one end of the field to the other; 4) solids removal from the ponds can largely be avoided a savings in cost and energy demand for solids removal and off site transport. Under new regulations, offsite transport will likely be required on most dairies in California for accumulated pond solids. Depending on the volume of manure pond and volume of solids accumulated, producers can easily spend tens of thousands of dollars to contract sludge pumping companies to remove solids from the manure ponds. Contingent on the rate of solids accumulation in lagoon, and the impact this has on storage volume, this can occur as often as once a year to as infrequently as once every ten years. University of California Cooperative Extension estimates that dredging lagoon solids costs from \$0.05 to \$0.10 per gallon. Because these solids are relatively dry when separated in front of the manure ponds, dewatering is not required and there are more options for reuse than for manure pond slurry. Energy savings have not yet been calculated.

3) Triple Cropping Dairy Forage Crops for Increased Crop Yields and Nutrient Cycling:

Triple cropping is a cultivation practice where three crops per year are grown instead of the usual two (typical here in California). The result is a decrease in the amount of forage/feed import to the farm. Also, more manure nutrients can be safely applied to fields at agronomic rates because of greater total nutrient uptake. While the practice is not uncommon in southern regions of the San Joaquin Valley, in the upper Valley where winters are cooler, triple cropping has rarely been achieved and has mostly been limited to years with optimal growing seasons.

However, with the demonstration and emerging recognition that conservation tillage (CT) is practical for dairy silage and forage crop production in the Central Valley the window of opportunity for triple cropping has increased to the point where it appears feasible in most years.

Producers using CT techniques typically plant their first spring crop weeks (sometimes months) in advance of producers who are implementing intensive cultivation practices. With intensive cultivation, producers must wait for the winter wheat to dry for it to be harvested and then also wait for the ground to dry before tillage can occur. Tillage itself can take a week or more to complete. If it rains anytime between harvesting of the winter crop and planting of the spring crop, the entire process is halted until the ground dries enough to continue cultivation and planting. This means that for years with wet, rainy, springs, such as spring of 2006 in the Central Valley, corn is often not planted until June. Alternatively, producers planting no-till corn can have their crop planted the same day the wheat is harvested. Over the past two years this has translated into over a month of additional growing season time. Further, planting the second summer crop can occur immediately after harvest of the first growing season crop as opposed to being delayed for a week or more while cultivation occurs. Typical rotations include corn – corn – winter crop (i.e. winter wheat), corn – sorghum-sudan – winter crop and corn – grain sorghum – winter crop.

With funding from the U.S. EPA and the USDA-NRCS, Sustainable Conservation has been working in partnership with the University of California Cooperative Extension and local custom planting companies to encourage the adoption of CT because of the associated environmental and economic benefits. Not only does CT protect soil from water erosion and reduce energy and financial costs associated with cultivation, U.C. researchers have measured dust (particulate matter) emissions reductions by as much as 85% Given the growing air quality concerns around particulate matter and diesel emissions in the San Joaquin Valley, the San Joaquin Valley Unified Air Pollution Control District recently included CT practices as an air emissions control technique.

Triple cropping as a nutrient management technique has emerged as an unanticipated environmental benefit from this work. Our farmer partners immediately seized on the time savings advantage of CT and have successfully implemented triple cropping since our first field trials in 2004. Economically, this allows producers to grow more feed on farm, reducing costs associated with purchasing feed from off-farm sources. Further, triple cropping increases total nutrient uptake per acre and maximizes recycling of manure nutrients on the farm as a fertilizer source for feed crops. From a nutrient management perspective, this increases the amount of manure that can be used on farm and reduces the amount of nutrients imported onto the farm via purchasing off-farm feed. Triple cropping with CT represents an environment triple win (for air, water quality and energy benefit) as well as financial cost savings, and is now being embraced by dairy producers. We are now evaluating triple cropping for other commodity crops as well as for biofuel crop production.

Literature Cited

California Dept. of Food & Agriculture (CDFA). 2005. California Dairy Statistics and Trends.

California Dairy Quality Assurance Program (CDQAP). 2004. Website homepage. http://www.cdqa.org/facts/

California Regional Water Quality Control Board (CRWQCB). 2006 (revised). The Water Quality Control Plan. Fourth Edition

Ken Krich (Editor) 2005. Biomethane from Dairy Waste – A Sourcebook for the Production and Use of Renewable Natural Gas. Western United Dairymen Publication.

Poster Abstracts

Session Chairs:

Mary Bianchi, UCCE San Luis Obispo County

POSTER SUBMISSION

Title of Paper:	Standardized Testing of an Amplitude Domain Reflectometry (ADR) Soil Moisture Sensor.
Author(s):	Diganta D. Adhikari, Dave Goorahoo and David Zoldoske and Florence Cassel S.
Contact Name:	Diganta D. Adhikari
Affiliation:	Center for Irrigation Technology
Address:	5370 N Chestnut Avenue M/S OF18
City:	Fresno
State:	CA
Zip:	93740
Telephone:	(559) 278 5289
Fax :	(559) 278 6033
Email:	diganta@csufresno.edu

ABSTRACT:

The development of Smart Water Application Technologies™ or SWAT™ was initiated by water purveyors who wanted to improve residential irrigation water scheduling. It is estimated that typical residential landscapes apply 30 to 40% more water than is required by the plants. Hopefully, the widespread adoption of "smart" controllers and soil moisture sensors would conserve a significant portion of the excess water applied. Over the past two years, the Center for Irrigation Technology (CIT) has been working closely with water purveyors statewide and the Irrigation Association (IA) as part of SWAT™ to develop standardized testing protocols for evaluating the reliability, accuracy and repeatability of commercially available soil moisture sensors. These sensors can provide closed-loop feedback to time-based system controllers, thereby allowing the controllers to recognize soil moisture levels and control irrigation events. In the current work, we apply the IA standardized testing protocol to an Amplitude Domain Reflectometry (ADR) moisture sensor. The efficacy of the sensor to perform under laboratory conditions of varying levels of moisture, soil type, and salinity was evaluated. For tests conducted at various temperatures and salinity levels for the medium and coarse textured soils, there was a high correlation between the volumetric water contents measured with the sensor and the calculated values, with r^2 values ranging from 0.94 to 0.99. For fine textured soils, we observed a lot of swelling and shrinkage of the soil which may have resulted in air gaps around the sensor probes. The correlation for a linear fit in the fine clay was found to be 0.92.

POSTER SUBMISSION

Title of Paper: Water Quality for Chinese Growers in Santa Clara County: Introducing Water and Nutrient Management Concepts.

Author(s): Aziz Baameur, Michael Cahn, Laosheng Wu
Contact Name: Aziz Baameur
Affiliation: UC Cooperative Extension, Santa Clara County
Address: 1553 Berger Dr. Bldg. 1
City: San Jose
State: CA
Zip: 95112
Telephone: 408-282-3127
Fax: 408-298-5160
Email: azbaameur@ucdavis.edu

ABSTRACT:

Chinese growers in the California's Central Coast area have recently begun to learn about water quality issues. UCCE and several local and regional agencies have committed to address the needs of this community whose primary means of communication remains Chinese.
The program focuses on five water quality areas: pest management, irrigation management, nutrient management, erosion control, and basic farm plan development. To date, three 3-hour workshops have been completed. Irrigation and nutrient management have been the most challenging. Over 95% of the operations are greenhouse based. Over 70% of the crops grown, presently, are Asian vegetables. A small number of operators still grow cut flowers, mainly chrysanthemum. The difficulty resides in three main factors: language barrier, the level of sophistication of the majority of the operators and their ability to understand technical information, and limited published information on nutrient and water needs for various Asian vegetable crops.
The training used a hands-on approach. The pertinent written materials were translated into Chinese. The materials were delivered to the growers simultaneously in English and Chinese. The 57 attendees learned how to evaluate existing greenhouse irrigation systems for irrigation and fertilizer distribution uniformity. The highlight of the sessions was the participation of the attendees in collecting the data that were the basis for the calculations and comparisons between two sprinkler types for uniformity. The attendees were also introduced to the concepts of fertilizer injection time, travel time, and flush time. They were provided with charts (Chinese/English) to help determine the amounts of fertilizer application based on product analysis and density (Lbs/gal), if liquid material is used.
Follow up workshops on fertilizer use, sprinkler selection, and crop water needs are being planned.

POSTER SUBMISSION

Title of Paper: Developing Co-Existence Methods for Genetically Engineered, Conventional and Organic Crops - San Luis Obispo County's Experience

Author(s): Mary Bianchi
Contact Name: Mary Bianchi
Affiliation: UC Cooperative Extension, San Luis Obispo County
Address: 2156 Sierra Way, Ste C
City: San Luis Obispo
State: CA
Zip: 93401
Telephone: 805-781-5949
Fax: 805-781-4316
Email: mlbianchi@ucdavis.edu

ABSTRACT:

At the request of the Chair of the County Board of Supervisors, the San Luis Obispo County Agricultural Commissioner formed a committee to discuss potential methods for co-existence of genetically engineered, conventional, and organic crops, including members from UC Cooperative Extension, California Certified Organic Farmers, San Luis Obispo County Farm Bureau, Cal Poly SLO Sustainable Ag Resource Consortium, Wine grape growers, Organic and specialty crop producers, and GE crop producers. The committee agreed on the definition of co-existence as "the simultaneous production of agricultural products within a common geographical area in which distinctly different production methods are used" assuming

- 'Distinctly different' = GE, Non-GE or organic production; and
- IF co-existence methods are successful, then growers can meet conventional and organic market requirements

The committee agreed to disagree on whether co-existence should or could occur. For the sake of discussion, committee members set aside personal and/or organizational beliefs regarding the value of genetic engineering in crop production. The committee undertook drafting non-regulatory and crop-specific guidelines for co-existence methods for winegrapes and sweet corn. Winegrapes are the #1 crop in value in the county, and sweet corn provided an example of an open-pollinated crop. Less than 500 acres of sweet corn are produced annually in San Luis Obispo.

Our committee has proposed 10 co-existence methods for discussion by SLO growers. Some of these proposed methods involve practices already used by local growers, e.g. prevention of pesticide drift from conventional to organic crops. Where possible we noted these current uses. The discussion is ongoing in the county.

POSTER SUBMISSION

Title of Paper: Lysimeter and Surface Renewal Estimates of Forage ET under Saline Irrigation

Author(s): Sharon E. Benes, Diganta Adhikari, Stephen R. Grattan and Richard L. Snyder

Contact Name: Sharon Benes
Affiliation: California State University, Fresno
Address: Dept. of Plant Science
2415 E. San Ramon Ave., M/S AS72
City: Fresno
State: CA
Zip: 93740-8033
Telephone: (559) 278-2255
Fax : (559) 278-7413
Email: sbenes@csufresno.edu

ABSTRACT:

Water use (ET) of three salt tolerant forages, tall wheatgrass (TWG, *Thinopyrum ponticum* var. 'Jose'), creeping wildrye (CWR, *Leymus triticoides* var. 'Rio'), and Paspalum (PASP, *Paspalum vaginatum* var. 'SeaIsle 1') was measured under irrigation with saline-sodic drainage water from the westside San Joaquin Valley of California. These forages are top candidates for drainage water re-use systems being developed for this area. The forages were grown in sand-filled, drainage lysimeters consisting of lined, sunken basins (1.3 m square) and irrigated with saline-sodic drainage water (ECw= 13.1dS/m, SAR= 23 and B= 20.0 mg/L). Cumulative ET (Jan. to Dec., 2005; 343 days) was 1470, 1376, and 1275 mm for TWG, CWR, and PASP, respectively, and reference ET ($CIMIS_{105}$) was 1500 mm. The resulting Kc's for the year were 0.98, 0.92, and 0.85 for these forages, respectively. During the summer, average daily ET was 7.95, 8.24, and 7.36 mm/day for TWG, CWR, and PASP, respectively which was equal to, or higher, than the reference ET of 7.37 mm/day. Surface renewal (SR) estimation of ET, which is based on soil heat fluxes and other micrometeorological variables, was used to verify the forage ET estimates obtained from the lysimeters. SR stations were installed in a 38-acre TWG field and a 20-acre CWR field rotationally grazed by beef cattle. The SR Kc for tall wheatgrass in 2005 was 0.998 which agreed well with the lysimeter Kc of 0.980. Surface renewal data for creeping wildrye are being processed. The ET data obtained thus far indicate a high degree of salt tolerance for these forages and the ability to consume saline drainage water which is desirable for drainage water re-use systems.

POSTER SUBMISSION

Title of Paper: Potential of Utilizing Ethanol CO_2 Emissions to Increase Crop Productivity and Water-Use Efficiency

Author(s): Florence Cassel S., Shawn Ashkan, Dave Goorahoo, Diganta Adhikari and David Zoldoske
Contact Name: Florence Cassel S.
Affiliation: Center for Irrigation Technology, California State University- Fresno
Address: 5370 North Chestnut Ave, M/S OF18
City: Fresno
State: CA
Zip: 93740
Telephone: (559) 278-7955
Fax : (559) 278- 6033
Email: fcasselss@csufresno.edu

ABSTRACT:

Carbon dioxide (CO_2) is the primary food of plants. Hundreds of experiments in the U.S. and around the globe have examined the effects of CO_2 enrichment on crop growth and production, and have verified enhanced crop yield and water-use efficiency of CO_2–enriched plants. Elevated CO_2 enhances photosynthesis and reduces stomatal conductance, thus crop and water productivity would increase considerably in elevated CO_2 conditions. Our previous studies in Fresno and southern coast of California indicate significant increases in total yield of fresh tomatoes and strawberries and a positive impact on water use efficiency for vegetable and fruits when exposed to elevated atmospheric CO_2 levels.

Ethanol production is growing in the San Joaquin Valley (SJV), which is one of the most productive agricultural areas of California. About 10 new ethanol plants are expected to be built in the near future in the SJV. These production facilities are expected to produce more than one million tons of CO_2 annually, which will be vented directly into the atmosphere if not captured and sequestered or used for beneficial purposes. In this presentation we outline the technology used to deliver the CO_2 and summarize the research conducted to date. Our findings to date imply utilizing CO_2 emissions from ethanol production facilities has good potential to enhance crop yield, water use efficiency, and farm income, while at the same time mitigate global warming by recycling CO_2 emissions in agricultural fields.

POSTER SUBMISSION

Title of Paper: Potential for AirJection® Irrigation in Organic Farming Systems

Author(s): Dave Goorahoo, Diganta D. Adhikari, David Zoldoske, Angelo Mazzei and Richard Fanucchi.
Contact Name: Dave Goorahoo
Affiliation: Department of Plant Science, CSU Fresno
Address: 2415 E. San Ramon Ave., M/S AS72
City: Fresno
State: CA
Zip: 93740
Telephone: (559) 278 8448
Fax : (559) 278 7413
Email: dgooraho@csufresno.edu

ABSTRACT:

Evaluating the impact of air via subsurface drip irrigation (SDI) system through the incorporation of high efficiency venturi injectors, referred to as AirJection® Irrigation, has been the focus of our research over the past five years. Our major objective has been to assess the technical and economic feasibility of AirJection® Irrigation as a best management practice for various crops in the San Joaquin Valley (SJV). So far we have tested the technology on bell peppers, fresh market tomatoes, cantaloupes, honeydews, broccoli and sweet corn. Recent and on-going research has shown that AirJection® Irrigation can increase root zone aeration and add value to grower investments in SDI. For example, in Summer 2004, for cantaloupes grown on 20-acre plots, there was a 13% increase in the number of melons and a 18% increase in the weight of melons harvested due to air injection. The increases in yield and improvement in soil quality associated with the root zone aeration augers well for the adoption of AirJection® Irrigation primarily as tool for increasing crop productivity. The work conducted to date has been aimed at evaluating the AirJection® Irrigation on conventional farms. However, because AirJection® Irrigation uses ambient air, there exists the potential to use this system on organic farms. In 2007, we intend to evaluate the AirJection® Irrigation system on land designated for transition to organic vegetable production at California State University-Fresno. In addition to yield and fruit quality, future studies should focus on the impact of air injection on water use efficiency, soil respiration, insect/pest resistance and rooting characteristics of the various crops.

POSTER SUBMISSION

Title of Paper: Nutrient Availability and Susceptibility of Corn to Common Smut

Author(s): Z. Kabir; P. Lazicki; W. Horwath
Contact Name: Zahangir Kabir
Affiliation: UC Davis Department of Land, Air and Water Resources
Address: One Shields Avenue
City: Davis
State: CA
Zip: 95616
Telephone: 530-754-6497
Fax :
Email: kabir@ucdavis.edu

ABSTRACT:

Common smut causal agent *Ustilago maydis* is a worldwide disease of corn (Zea mays L.) which can cause severe economic loss. The aim of study was to investigate the relationship between soil and plant nutrients and common smut (*Ustilago maydis*) severity in 2005 and 2006. The study was conducted in the Sustainable Agricultural Farming Systems (SAFS) project in three farming systems: conventional (source of N fertilizer from NH_4NO_3), low-input (source of N from winter legume cover crop) and organic (source of N from manure and winter legume cover crop). Within each system, corn was grown under standard (ST) and conservation tillage (CT) practices. Common smut disease severity was lowest in the conventional, highest in the low-input and intermediate in the organic regardless of tillage practices. Tissue analysis revealed that corn plants grown in the conventional system had the highest N and P content, while plants grown in the low-input systems had the lowest. These results indicate that nutrient availability could affect a corn plant's susceptibility to common smut.

POSTER SUBMISSION

Title of Paper: Relations Between Soil Nitrate, Tissue Nitrogen and Corn Yield Under Conventional and Alternative Farming Systems

Author(s): Z. Kabir; P. Lazicki; W. Horwath
Contact Name: P. Lazicki
Affiliation: UC Davis, Department of Land, Air and Water Resources
Address: One Shields Avenue
City: Davis
State: CA
Zip: 95616
Telephone: 530-754-6185
Fax :
Email: patricia.lazicki@gmail.com

ABSTRACT:

Nitrogen management is a major challenge to the success of alternative farming systems. While conventional farmers apply N in a form directly available to the crop, organic farmers must incorporate it in the form of organic matter, relying on the N cycle to provide N to their crops. A serious result of this indirect nutrient provision is that N availability may not coincide with crop uptake, resulting both in yield reduction and environmental damage. This study compares the nitrogen use efficiency in a conventional and two alternative farming systems: one completely organic and one receiving N both in organic form as a winter legume cover crop and in inorganic form as a small amount of NPK applied at planting. Plant and soil samples were collected four times per season from 2003-2006, and subsequently analyzed for nitrate and total N. Soil nitrate was generally higher throughout each season in the two alternatively managed systems than in the conventional; however, by harvest time there was no significant difference between the three. Similarly tissue NO_3^- and % total N were initially similar between the three systems, but by harvest time the tissue from the conventionally managed corn was significantly higher in both. In all years, corn yield was significantly greater in the conventional system than for either of the two alternatives. Our results indicate that the alternative systems were able to provide the corn with N early in the season and did not have, overall, significantly less soil NO_3^- than the conventional system. However, these systems were unable to provide the crop with enough N to sustain it in the later stages of growth and achieved lower yields

POSTER SUBMISSION

Title of Paper: Linking changes in early season water management to changes in nitrogen dynamics in California rice systems

Author(s): Kaden Koffler, Bruce Linquist, Jim Hill, Luis Felipe Tiene Da Silva, Cass Mutters, Chris Greer, and Chris van Kessel
Contact Name: Kaden Koffler
Affiliation: Department of Plant Sciences, University of California, Davis
Address: One Shields Avenue
City: Davis
State: CA
Zip: 95616
Telephone: 530-752-3457
Fax :
Email: kbkoffler@ucdavis.edu

ABSTRACT:

Many rice growers are beginning to change early season water management to facilitate the use of newer herbicides, such as "*Clincher*". Growers drain their fields within a couple weeks following seeding, and once dry enough, apply herbicides by ground. Shortly following the herbicide application, the fields are reflooded.
In two on-farm experiments near Live Oak, we measured changes in N dynamics resulting from the flooding-drying-reflooding of rice fields in the early season. Each field had two treatments, each replicated 3 times in a randomized complete block design. The treatments were imposed by forcing 30" diameter iron rings into the soil, creating a seal so that water could either be kept in or out of the rings, depending on the treatment. The first treatment (*Drained*) was the farmer practice of draining the field within 2 weeks after seeding, a period of drying, followed by a "*Clincher*" application, and finally reflooding. In the second treatment (*Undrained*), the flood water was maintained throughout the early season.
Draining the fields for a period of 7 to 10 days led to an accumulation of soil nitrate (20-30 lb N / acre), which disappeared within 20 days following reflooding. At harvest, N uptake and yield were higher in the *Undrained* than in the *Drained* treatment, by 15 and 340 lb / acre, respectively. This suggests the drain caused nitrate loss through denitrification, which had a negative impact on yield. Rice growers using early season wetting-drying practices may need to reevaluate their N management strategies.

POSTER SUBMISSION

Title of Paper: Evaluating Potential Impacts of Land-Applied Food Processing By-Products on Soil Quality and Plant Nutrients

Author(s): Sajeemas (Mint) Pasakdee[a] & Nat Dellavalle[b]
Contact Name: Sajeemas (Mint) Pasakdee, Ph.D., Soil Scientist/Agronomist
Affiliation: [a]California Agricultural Technology Institute, California State University Fresno; [b]Dellavalle Laboratory Inc. Fresno, California.
Address: California Agricultural Technology Institute (CATI), California State University Fresno
2910 East Barstow Ave. M/S OF 115,
City: Fresno,
State: CA
Zip: 93740
Telephone: 559-278-2828, Cell: 559-577-3981
Fax: 559-278-4849
Email: spasakdee@csufresno.edu

ABSTRACT

Food processing canneries, especially those using raw fruit, nut, and vegetable- base materials, generate various types of by-products or non-hazardous wastes. The constituents of these wastes are dependent on the source of raw material and the substances associated with the canning processes. The use of land-applied non-hazardous wastes as an agricultural soil amendment is projected to rise because of public concerns regarding environmental impact and economic restraints of their disposal to landfill or incineration, as well as because of presumed inherent agricultural benefits. This practice is important not only for recycling nutrients back into the soil, but also for minimizing those elements of concern (e.g. nitrogen, sodium, chloride, and trace elements) that would otherwise be concentrated elsewhere. Public concerns regarding the impact of food processing by-products (which contain low pH, high TDS, and trace elements) are that they may impair soil quality upon application to California farmlands. The primary goal of this project was to develop best management practices for sustainable reuse food processing by-products as a soil amendment for California farmlands. We evaluated effects of land-applied food processing by-products on soil chemical properties and trace element accumulations in plant tissues under the Permit Program established by Dept. of Environmental Resources, Stanislaus County. The preliminary results from this study will be discussed.

POSTER SUBMISSION

Title of Paper: Rice Straw Management and Water Quality in the Sacramento Valley

Author(s): M.D. Ruark, B.A. Linquist, C. van Kessel, J. Six, C.A. Greer, R.G. Mutters, and J.A. Hill
Contact Name: Dr. Matthew D. Ruark
Affiliation: University of California, Davis
Address: Department of Plant Sciences, One Shields Ave,
City: Davis
State: CA
Zip: 95616
Telephone: (530) 752-3457
Fax : (530) 752-4361
Email: mdruark@ucdavis.edu

ABSTRACT:

With the regulated reduction of straw burning in the Sacramento Valley, flooding of rice fields during winter months has become a standard management practice to facilitate the breakdown of rice residues. Furthermore, the keeping of rice straw in-field may lead to an increase in dissolved organics, nutrients, and metals exported during flooding. Little information is available regarding the potential increase in dissolved organic carbon (DOC), nitrate-nitrogen (NO_3-N), and dissolved phosphorus (DP) export from rice fields under various straw managements. The objectives of this study were to measure seasonal losses of DOC, NO_3-N, and DP from rice production fields and to compare these losses between burned and incorporated fields. Four grower field sites were used for this study, with burned and straw incorporated fields located at each site. These fields were located throughout the Sacramento Valley and encompass a range of soil types and water managements. Water samples were collected from field inlets, field outlets, and lateral or peripheral drains during winter flooding and within-growing season flooding. Winter flooding was only conducted on two of the incorporated fields in 2005. The DOC concentrations during maintenance flow ranged from 40 to 50 mg L^{-1} in early November and decreased to below 10 mg L^{-1} by early February. Within-growing season flooding in 2006 led to more direct comparisons of DOC loss between burned and unburned fields. The DOC concentrations typically decreased over time, but there were no consistent effects of straw management on DOC concentrations. The differences in water managements among all sites may have caused these inconsistent temporal trends and potential differences between straw managements. A complete analysis of all measured variables will be presented.

POSTER SUBMISSION

Title of Paper: Soils to Go

Author(s): Jerry Schmierer and Kris Lynn-Patterson
Contact Name: Jerry Schmierer
Affiliation: Univ. of California, Cooperative Extension
Address: PO Box 180
City: Colusa
State: CA
Zip: 95932
Telephone: 530-458-0575
Fax : 630-458-4625
Email: jlschmierer@ucdavis.edu

ABSTRACT:

Soils to Go is a web based Geographic Information System (GIS) at http://gis.uckac.edu that allows users to interact with the soils, land use, topography and other landscape information of California Counties.
The "Soils to Go" geographic information system (GIS) is a compilation of publicly available information and a methodology for interaction with that information. This is a full featured web based GIS that provides data layers for California Counties. These layers include information derived from the SSURGO Soils Database in an abbreviated format, land use, water district and political boundaries, roads, waterways, township, range and section information along with historic topography maps and aerial imagery. Users can drill down through the information in the databases and view the printable data. Data layers can be queried and selected attributes displayed. Manual data input by users are allowed. Map selections can be printed or emailed. User GIS sessions can be saved for later retrieval by the user. The purpose of "Soils to Go" is to provide geographic landscape information for California counties in a user friendly GIS format delivered via the web for the general public use. The initial phase of this project included the seventeen San Joaquin Valley and Sacramento Valley Counties in California.

POSTER SUBMISSION

Title of Paper:	Nitrogen Uptake by Broccoli from a Legume/Cereal Mix Cover Crop
Author(s):	Joji Muramoto, Richard Smith, Jim Leap, Carol Shennan and Stephen Gliessman
Contact Name:	Richard Smith
Affiliation:	University of California Cooperative Extension, Monterey County
Address:	1432 Abbott Street
City:	Salinas
State:	CA
Zip:	93901-4507
Telephone:	831-759-7350
Fax :	831-758-3018
Email:	rifsmith@ucdavis.edu

ABSTRACT:

Two trials were conducted to evaluate the contribution of nitrogen from a legume/cereal mix cover crop. Trial No. 1 was conducted at the Center for Agroecology and Sustainable Food System organic farm in University of California Santa Cruz and Trial No. 2 at the Hartnell East Campus Research Facility in Salinas. Cover crops were grown over the winter and incorporated into the soil in the spring. A randomized block design or a split plot design was utilized with cover crop and no cover crop as the main plots and 0, 75, 150 and 225 lbs N/A as the other main plots (Trial No. 1) or the split plot treatment (Trial No. 2). Broccoli was grown to maturity and mineral nitrogen (N) in the top foot of soil was measured over the season, tissue nitrogen was measured at midgrowth and at harvest, and harvest evaluations were conducted. The cover crop in Trial No. 1 containing 160 lbs N/A. N uptake by broccoli indicates 27 and 37 lbs more N broccoli biomass in the cover crop treatments at midgrowth and at harvest, respectively. In particular, the 37 lbs N/A increase at harvest was approximately equivalent to the increase brought about by 75 lbs-N/A of organic fertilizer application. The cover crop in Trial No. 2 contained 194.5 lbs N/A. Twelve inches of rain fell between incorporation of the cover crop and planting the broccoli and it is assumed that a sizeable portion of mineralized N from the cover crop was lost to nitrate leaching. Evaluations of N uptake indicate 20 and 27 lbs more N broccoli biomass in the cover crop treatments at midgrowth and at harvest, respectively.

POSTER SUBMISSION

Title of Paper: Managing soil food webs for enriched and suppressive soils: impacts of cover crop attributes and diversity.

Author(s): Tianna DuPont, Howard Ferris
Contact Name: Tianna DuPont
Affiliation: UC Davis, Integrated Pest Management Graduate Group
Address: 354 Hutchinson Hall, University of California at Davis
City: Davis
State: CA
Zip: 95616
Telephone: 530-752-2124
Fax :
Email: stdupont@ucdavis.edu

ABSTRACT:

Agricultural landscapes are often deficient in soil food web diversity due to frequent disturbance from tillage and chemical inputs. Yet soil organisms perform important ecosystem services such as nutrient cycling, pathogen and pest suppression which are particularly important in low-input and organic systems. As natural systems have evolved over millennia to effectively regulate disease and nutrient availability, we attempt to create the traits which underlie their success. The traits include high plant species richness, perennial species and minimal disturbance. Nematodes are indicators of soil health and ecosystem services. They are represented at all trophic levels in the soil and regulate many soil functions, thus nematode abundance and diversity indices reflect overall composition and functioning of the soil food web. We are studying the nematode community and the soil food web of natural systems to assess the capacity of various management practices to return agricultural soil to a more naturally productive and disease suppressive state. Natural systems under evaluation include the California Quail Ridge Reserve Oak woodlands and Kansas undisturbed bottomland prairie. Our objective is to provide farmers with management practices that are based on the functioning of natural systems. Comparison of management practices that include plant species diversity and perennial are evaluated in field and mesocosm trials at UC Davis and Land Institute field sites in Kansas.

STUDENT POSTER SUBMISSION

Title of Paper: Rebuilding Delta Soils: The Effect of Differing Amounts of Rice Straw Amendment on Dissolved Organic Carbon Over Time

Author(s): Ian S. Bay, William R. Horwath, Steve Deverel
Contact Name: Ian S. Bay
Affiliation: UC Davis, Department of Land, Air, Water Resources
Address: 1111 PES Building, 1 Shields Ave.
City: Davis
State: CA
Zip: 95616
Telephone: (530)754-6185 (Lab)
Fax :
Email: isbay@ucdavis.edu

ABSTRACT

Subsidence of agricultural peat soils and the resultant weakening of levees in the Sacramento-San Joaquin Delta has led to the question of rebuilding Delta soils in order to counteract lowering soil levels and to reinforce levees in that region. One possibility being considered is using available rice straw covered with dredge sediment to rebuild soils with the goal of restoring wetlands. One major concern, however, is the possible consequent elevation of dissolved organic carbon (DOC) concentrations in Sacramento-San Joaquin Delta water when used for drinking. Upon treatment for drinking, DOC can form trihalomethanes. The concern, then, when adding organic amendments to Delta soils is to what extent these amendments will form DOC, and what happens to the concentrations of DOC over time. In order to address this concern, 100-day incubations of peat soil, C-13, rice straw, dredge sediment, and Sacramento-San Joaquin Delta water were evaluated for DOC levels, CO2 rate of release, specific ultraviolet absorbance (SUVA), as well as other parameters. Over the course of the 100 days, DOC concentrations went from an initial 70-80 ppm to a peak of 700-800 ppm. Then returned and leveled off at 220-230 ppm. The data showed that differing levels of rice straw had little, if any, effect on the amount of DOC produced. This was true even though about half of each treatment amount of rice straw was decomposed in all cases. In addition, the results showed that the percent of DOC from straw by Day 100 was relatively small compared to that produced by the peat soil.

STUDENT POSTER SUBMISSION

Title of Paper: Quantifying the Aspect Effect

Author(s): Dylan E Beaudette and Anthony T. O'Geen
Contact Name: Dylan Beaudette
Affiliation: University of California at Davis
Address: One Shields Ave
City: Davis
State: CA
Zip: 95616
Telephone: 530-754-7341
Fax :
Email: debeaudette@ucdavis.edu

ABSTRACT:

Aspect angle is used by soil scientists as a proxy for the variation in surface moisture dynamics across the landscape. It is common practice to generalize aspect angle even further to the notion of "cool" and "hot" slopes when mapping soils. With the abundance of high resolution digital elevation models and climatic data, it is now possible to quantitatively model surficial moisture status. Solar radiation models, such as SRAD, SOLPOS and the ESRA model, can numerically describe the components of a solar radiation budget at each cell of a digital elevation model for any time duration. Numerous settings allow for site-specific calibration of climatic parameters, vegetation coverage, and surface albedo. Parameterization of the atmospheric clarity is usually accomplished with the Linke turbidity factor, a number which can be derived from local pyranometer measurements. Preliminary work at the Pinnacles National Monument suggests that mean annual solar radiation values on north and south aspects can differ by as much as two-fold. Analysis using a 300 pedon database has shown that key surficial properties such as presence of mollic epipedon, presence of a litter layer, color, total carbon and total nitrogen can be directly linked to modeled solar radiation values. Results of this nature may be of initial value to soil scientists when mapping a new region, in classifying regions of similar "solar profiles". Future work will incorporate our findings into a regional project which integrates various process-based models into a unified, energy flux approach to modeling pedogenesis.

STUDENT POSTER SUBMISSION

Title of Paper: Temporal variability in water quality of agricultural tailwaters: Implications for monitoring strategies

Author(s): Neil E. Brauer, Anthony T. O'Geen, Randy A. Dahlgren, Jonathan J. Maynard
Contact Name: Neil Brauer
Affiliation: U.C. Davis Department of Land Air and Water Resources
Address: 1 Shields Ave,
City: Davis
State: CA
Zip: 95616
Telephone: (530)-792-1525
Fax :
Email: nebrauer@ucdavis.edu

ABSTRACT:

Quantifying variability of agricultural tailwaters is of particular pertinence to the Agricultural Discharge Waivers Program which mandates growers and/or coalition groups monitor water quality in agricultural watersheds. Due to the expensive nature of water quality analysis, it is crucial to streamline monitoring protocols to minimize sample number without compromising accuracy. Intensive, season-long monitoring of an agricultural drain that discharges into the San Joaquin River revealed significant temporal variability in concentrations of nutrients, salts, and turbidity over intra-daily scales, as well as significant seasonal and diel patterns. Mean total N was 8.53$\pm$ 7.81 ppm. Mean total P was 543$\pm$ 751 ppb. Statistical techniques were applied to our high resolution dataset in order to evaluate the optimum sample size needed to fall within a given confidence interval of the true seasonal mean, as well as to evaluate the efficacy of different sampling strategies (e.g. grab samples vs. composite samples.) The use of daily composite samples presents itself as a viable means to maintain accuracy and resolution, while diminishing required sample number for some constituents by 50%. Significant correlations between electrical conductivity, nitrate nitrogen, and total nitrogen, suggest that electrical conductivity may serve as a proxy for these constituents. The results of this study show that the widely used practice of bi-weekly sampling for water quality parameters is insufficient to capture the variability of agricultural tail-water systems. This study will provide guidance for growers and water resource regulators to develop economically viable and science-based monitoring protocols for irrigated agriculture.

STUDENT POSTER SUBMISSION

Title of Paper:	Infiltration rates for soils under long term irrigation with saline-sodic drainage water: Methodology and Preliminary results
Author(s):	Vijay Chaganti, Dave Goorahoo, Sharon Benes, and Diganta Adhikari
Contact Name:	Sharon Benes
Affiliation:	California State University, Fresno
Address: :	Dept. of Plant Science 2415 E. San Ramon Ave., M/S AS72
City:	Fresno
State:	CA
Zip:	93740-8033
Telephone:	(559) 278-2255
Fax :	(559) 278-7413
Email:	sbenes@csufresno.edu

ABSTRACT:

Re-use of saline-sodic drainage water (DW) for the irrigation of salt tolerant field crops and forages is an important tool for salinity and drainage management on the Westside San Joaquin Valley of California. The sodic nature of this DW can cause clay dispersion and reduced infiltration of water into soils. Proper irrigation management and on-going soil reclamation will be needed to ensure the sustainability of these DW re-use systems. This study will characterize the infiltrability of soils in three stages of the Red Rock Ranch, Integrated On-Farm Drainage management (IFDM) system and assess the reclamation potential of gypsum, sulfur, and poultry manure for these soils. Stage 1 soils have always been freshwater-irrigated while those in Stages 3 and 4 are highly dispersed due to irrigation with DW averaging 11.7 and 12.9 dS/m ECw, respectively, for seven or more years. The four soil amendment treatments (gypsum and poultry manure at 10 ton/acre/application, sulfur at 2 ton/acre/application, and a non-amended control; each replicated three times) were applied to 1 m^2 plots using a split plot design. The main plot factor is the soil amendment and the sub-plot factor is the salinity of the infiltrating water (0.5 dS/m, 6 dS/m, and 12 dS/m). Infiltration is measured with Decagon "mini-disk infiltrometers" at three suctions (0.5, 2 and 6 cm) which represent different soil tensions. Infiltration was measured in November prior to the first soil amendment application and will continue to be measured just prior to each of the twice-yearly, amendment applications. The initial infiltration data, prior to the application of soil amendments, will be presented.

STUDENT POSTER SUBMISSION

Title of Paper: EC and SAR Effects on the Hydraulic Conductivity of Santa Clara County Soils

Author(s): Jocelyn Evans and Mike Singer
Contact Name: Jocelyn Evans
Affiliation: UC Davis
Address: 1014 Sycamore Ln
City: Davis
State: CA
Zip: 95616
Telephone: 530.574.2259
Fax :
Email: jevans@ucdavis.edu

ABSTRACT:

Several sites in Santa Clara County, Ca, are, or will be irrigated with tertiary treated wastewater with a sodium adsorption ratio (SAR) of 4. Treated wastewater is known to cause soil swelling and dispersion due to high sodium contents and low electrical conductivity. Research has shown that decreases in hydraulic conductivity (HC) occur as solution electrical conductivity (EC) decreases for a given SAR, and that a soil's saturated HC is most affected by solutions of a higher SAR. Water quality thresholds and soil hydraulic conductivities were determined for 30 soils from Santa Clara County, Ca. Solutions with an SAR of 3, 6 or 12, and with total salt concentrations of 500, 100, 50, 10, 5, 1, and 0 mmolc/L were passed through soil columns using a constant head. Flux rates were measured to determine saturated hydraulic conductivity. Soil properties including texture by pipette, soil cation exchange capacity (CEC), mineralogy and organic and inorganic carbon content were also determined to understand the hydrologic behavior of these soils. The greatest decline in hydraulic conductivity occurred with SAR 12 solutions that were at or below a total salt concentration of 5 mmolc/L. Saturated hydraulic conductivities were most affected at clay contents of 40 percent, by the presence of high activity clays, and larger exchange capacities. In contrast, only small decreases in saturated HC were observed for samples that were largely composed of coarser fractions.

STUDENT POSTER SUBMISSION

Title of Paper:	Impact of Agricultural Management Practices on Sediment and Nutrient Losses to Runoff

Author(s):	S. Ma, Z. Kabir, A. Ristow and W. Horwath
Contact Name:	Stephanie Ma
Affiliation:	UC Davis Department of Land, Air and Water Resources
Address:	One Shields Avenue
City:	Davis
State:	CA
Zip:	95616
Telephone:	530-754-6185
Fax :	
Email:	sama@ucdavis.edu

ABSTRACT:

Given government pressure on growers to reduce water pollution from field runoff, it is vital to link alternative agricultural management practices with their effect on water quality. In this experiment water was collected and analyzed from both research plots and grower fields under different agricultural management practices to determine the effects of the practices on runoff quantity and quality. Farming practices that preserve or enhance soil cover entering the rainy season appear to be effective at reducing cumulative runoff and, hence, nonpoint source pollution (NPSP) loads. Adherence to conservation tillage (CT) practices can immediately reduce fuel costs, but the potential benefits to water quality may take years to realize. In the short term, growers may have other water conservation options, including reconfiguring fields to reduce runoff velocity and thus erosion. On a farm scale, winter cover crops (WCC) significantly reduce winter runoff, but also may affect subsoil water recharge and soil moisture content at the time of planting. The potential for WCC to alter the water budget of subsequent crops under furrow irrigation systems poses important questions, considering future water supply concerns. Additional research is needed to develop conceptual models that correlate water inputs and load reductions with alternative agricultural management practices in California. Such information would be beneficial to water quality stakeholders hoping to address future quality and supply issues.

STUDENT POSTER SUBMISSION

Title of Paper: Effects of sedimentation on phosphorus retention in seasonally submerged wetland soils

Author(s): Jonathan J Maynard, Anthony T O'Geen , Randy A Dahlgren
Contact Name: Jonathan Maynard
Affiliation: University of California, Davis
Address: One Shields Ave.
City: Davis
State: CA
Zip: 95616
Telephone: 530.754.7341
Fax :
Email: jjmaynard@ucdavis.edu

ABSTRACT:

Irrigation induced erosion is one of the leading sources of pollution affecting water quality nationwide. In California's Central Valley, constructed wetlands (CWs) are used as best management practices (BMPs) for the treatment of agricultural return flows containing high levels of sediment and nutrients. The ability of wetland soils to retain phosphorus is an important property in determining their treatment efficiency. This study examines the spatial relationships between wetland soil properties and their ability to sorb phosphorus. A 13 year-old constructed wetland receiving agricultural tailwaters was monitored during the 2004 and 2005 irrigation seasons (May-Sept.). Sedimentation samples (n=50+) were collected at the end of years 1 and 2 and analyzed for organic carbon, total nitrogen, total phosphorus, Olson-P, particle size, soil organic matter, crystalline and poorly crystalline iron- and manganese-oxides, and phosphorus sorption index (PSI). Geostatistical methods were used to determine the spatial variability of each soil property and to determine which properties best explained the variability of PSI. Results from this study show that PSI had the highest partial correlation with clay sized particles ($r=0.403$ $p=0.000$) and poorly crystalline Fe ($r=0.369$ $p=0.000$). Moreover, autocorrelation in spatial patterns demonstrated that poorly crystalline Fe was lowest at the inlet and increased with distance along the flowpath. Flowpath plays a major role in the spatial distribution of sedimentation, which directly affects spatial patterns of P sorption. The continual input of sediment on the wetland floor, followed by periods of wetting and drying, promotes the formation of amorphous iron oxides and the replenishment of sorption sites. Thus, cyclic periods of wetting and drying, when combined with high rates of sedimentation, can provide a replenishment of P sorption sites and maintain the effectiveness of CWs as a BMP for P retention.

STUDENT POSTER SUBMISSION

Title of Paper: Water Quality and Irrigated Rangeland in the Upper Feather River Watershed

Author(s): Laura Murphy, Michael J. Singer, Ken Tate and Holly George
Contact Name: Laura Murphy
Affiliation: University of California, Davis
Address: Land, Air and Water Resources; 1 Shields Ave
City: Davis
State: CA
Zip: 95616
Telephone: 530-752-6081
Fax : 530-752-1552
Email: mismurphy@ucdavis.edu

ABSTRACT:

Potential water quality impacts from grazed rangeland irrigation return flows include temperature changes, nutrient enrichment, bacterial contamination, and sediment discharge. The Upper Feather River watershed, in California's northern Sierra Nevada, includes approximately 60,000 acres of irrigated range lands, located primarily within Sierra Valley, Indian Valley and American Valley. The objective of this project is to determine the current status of pollutant levels above and below the major irrigated agriculture systems in the Upper Feather River Watershed. During the 2005 and 2006 summers, water samples were collected from nineteen sites. Electrical conductivity, pH, total nitrogen (N), nitrate (NO_3), ammonium (NH_4), total phosphorus (P), phosphate (PO_4), total and dissolved organic carbon (TOC/DOC), turbidity, total suspended solids, and E. coli were measured by standard methods. Data from the initial sampling (2005) suggest that water quality is not impaired at most sites for most of the time. (Mean values for all sites are given in parentheses following the constituent.) In general, no site contained appreciable PO_4 (0.01 ppm) or NH_4-N (0.01ppm). Electrical conductivity was low at all locations (131 µS/cm). NO_3 (0.09 ppm), N (0.28 ppm) and DOC (2.77 ppm) showed increased concentrations associated with decreased flows. This trend is expressed spatially, from above the valley to below, and temporally, from May to September. E. coli concentrations (123cfu/100ml) did not follow any spatial pattern, but during late summer low flows, concentrations at some sites greatly exceeded the state mandated threshold of 235 CFU/100 ml. Future sampling will focus on pinpointing sources of E. coli within the watershed. Also, sampling on ranches will help bracket pollution sources and assist in developing cost-effective best management practices to reduce water quality impairment.

STUDENT POSTER SUBMISSION

Title of Paper: Respiration, Oxygen and Moisture Profiles for Soil Subjected to AirJection® Irrigation: Methodology and Preliminary Results

Author(s): Namratha Pulla Reddy Gari, Dave Goorahoo, Diganta Adhikari and Shawn Ashkan
Contact Name: Namratha Pulla Reddy Gari
Affiliation: Plant Science Department, California State University- Fresno
Address: 2415 E. San Ramon Ave MS AS 72
City: Fresno
State: CA
Zip: 93740
Telephone: (559) 278-8448 (Advisors office), Cell: (559) 907 2231
Fax : (559) 278- 7143
Email: nammi@csufresno.edu

ABSTRACT:

The concept of aerating the irrigation water increases the potential for the air to travel with water within the root zone. Physical, chemical, and biological soil characteristics that influence crop growth and yield depend on the relative proportions of the liquid and gas phases within the root zone. To date the major objective of research at the Center for Irrigation Technology (CIT) has been on evaluate crop yield and quality due to the impact of air via subsurface drip irrigation (SDI) system through the incorporation of specially designed venturi injectors, referred to as AirJection® Irrigation.

As of November 2006, our research focus has been to determine the moisture and oxygen profiles in the root zone of air injected soils. In addition we intend to measure soil respiration rates for vegetable beds subjected to the aerated and non aerated water. In this presentation we review the methodology used to log moisture and oxygen data, as well as periodic soil respiration measurements, at two stations 200 feet apart along the drip tape.

For soil moisture, we used a Time Domain Reflectometry (TDR) system comprising of a Campbell Scientific Inc. datalogger, a TDR100, multiplexers, and CS635 sensors. The oxygen sensors used were galvanic cell type, with a lead anode, a gold cathode, an acid electrolyte and a Teflon membrane. Current flow between the electrodes was proportional to the oxygen concentration. A CIRAS 2 photosynthesis-soil respiration system was used to determine soil respiration rates at the two stations. Basically, a chamber with known volume was placed on the soil and the rate of increase in CO_2 within the chamber was monitored. Data collected during November 2006 is currently being analyzed and will be presented along with the additional experiments conducted during December and January.

STUDENT POSTER SUBMISSION

Title of Paper: Effects of Temperature on Cotton Ovule Development and Yield

Author(s): Lisa Ratto, Adroniki Bibi, Derrick Oosterhuis, and Bruce Roberts
Contact Name: Lisa Ratto
Affiliation: California State University Fresno
Address: 2252 Sheridan Way
City: Stockton
State: CA
Zip: 95207
Telephone: 209 471-2241
Fax :
Email: lratto@csufresno.edu

ABSTRACT:

High temperatures during the flowering period have been associated with poor boll retention and final yields in cotton. To study this association, a collaborative project was initiated between the University of Arkansas and CSU Fresno to investigate the relationship between temperature and cotton ovule development. The objective of the project is to determine what effects high temperatures have on ovule development and overall yield when they occur during critical reproductive developmental stages. The California site was in addition to field sites located in Arkansas, Greece, and Australia. Only the California data will be discussed in this presentation. Flower samples were taken on weekly intervals and sent to the University of Arkansas for ovule analysis. Final boll samples were forwarded for final seed evaluation. This method provided information on the potential and realized seed set as affected by temperatures. Data on plant biomass accumulation and final seed cotton yields were also collected. The planting arrangement at CSU Fresno allowed comparisons between two Upland cotton varieties and a Pima variety.
The 2006 season in the San Joaquin Valley was characterized by excessively high temperatures during the critical bloom period. Preliminary results suggest different responses between the cotton varieties and the temperatures experienced in the 2006 season. The relationship between the number of potential ovules in the flower samples, developed seed in the final boll samples, and the final cotton yields will be explored within our final results.

STUDENT POSTER SUBMISSION

Title of Paper: Long-term assessment of N use and loss in irrigated organic, low-input and conventional cropping systems

Author(s): W. R. Horwath; Z. Kabir; K. Reed; S. Kaffka; J. Mitchell; G. Miyao; K. L. Brittan
Contact Name: Kathleen Reed
Affiliation: UC Davis Department of Land, Air and Water Resources
Address: One Shields Avenue
City: Davis
State: CA
Zip: 95616
Telephone: 530-220-3826
Fax :
Email: kathleen@antfarm.org

ABSTRACT:

In order to achieve optimum N availability, organic and low-input farming systems require greater carbon inputs than conventional systems. The build up of soil organic matter is required to increase the potential for N mineralization. The diverse inputs of these systems impact nitrogen balance, soil storage, and loss. Organic (N from manure and winter legume cover crop), and low-input (N from reduced fertilizer and winter legume cover crop), farming systems are compared with conventional (N from fertilizer) systems at two long-term research experiments, 1989-1998 at the Sustainable Agriculture Farming Systems (SAFS) site, and 1993-2006 at the Long Term Research in Agricultural Systems (LTRAS) site, both at the University of California, Davis, to evaluate long-term nitrogen use. At both sites, the organic system had the greatest cumulative N input and N balance, while the conventional system had the highest N output. Although the organic system had the greatest cumulative N input, it showed the lowest N output of all the systems. Soil N storage at both sites was highest in the organic system. Yields for both corn and tomato were comparable among all three farming systems at the SAFS site, while at the LTRAS site corn yields over the duration of the experiment were consistently higher in the conventional system, increasing over time. In the low-input and organic systems however, corn yields were consistently lower, decreasing over time. Our results indicate the challenge in optimizing crop N uptake in organic and cover crop based systems does not entirely rely on developing organic matter pools to increase N mineralization potential. Rather it is more important to influence the rate and timing of N mineralization.

STUDENT POSTER SUBMISSION

Title of Paper: Effects of Prescribed Fire on Soil Properties in an Oak Woodland Landscape

Author(s): Alexandre Swarowsky, Anthony O'Geen, Randy Dahlgren, Ken Tate , David Lewis
Contact Name: Alexandre Swarowsky
Affiliation: University of California at Davis
Address: One Shields Avenue
City: Davis
State: CA
Zip: 95616
Telephone: 530-754-7341
Fax :
Email: aswarowsky@ucdavis.edu

ABSTRACT:

Oak woodlands are used extensively for cattle grazing, providing approximately 75% of the forage produced on California's rangelands. Grazing and prescribed fire are critical vegetation management tools allowing managers to maintain economically feasible agricultural enterprises , open space , reduce fuel loads, improve habitat for certain wild life species , and manage weed infestations . Grazing and prescribed fire are the most cost effective vegetation management tools available to rangeland managers. This study is part of a larger project designed to evaluate the impacts of rangeland management on water quality.

Prescribed fire treatments were completed in two oak woodland watersheds at UC Hopland and Sierra Foothill research and extension centers. The top 3-cm of soil was sampled before and after burning for nutrient analysis. Biomass was collected before the burn.

Soil organic carbon did not change after prescribed fire and nitrogen increased. Under oak, 32% of biomass-N was supplied to soil after burning, corresponding to 20.2 kg ha-1 increase. The remaining 68% of biomass-N was lost through volatilization. In open grass, 34% of biomass-N was supplied to soil after burning, corresponding to a 14.6 kg ha-1 increase. The N returned to soil after fire was low, less than the amount supplied as manure at stocking rates of 3 cows per hectare. Phosphorus has higher volatilization temperatures (>500°C) compared to nitrogen (200°C), thus the relative amount of P returned to soil after burning was higher. Results suggest that prescribed fire will not increase nutrient supply to streams since very little N was released. This is likely the case for P because its mobility is limited in soil; however, transport by accelerated erosion may be amplified by fire.

Notes

Notes

Notes

Notes

California Chapter – American Society of Agronomy
2007 Plant and Soil Conference Evaluation

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

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

1. Conference Evaluation

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

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

a. ____

b. ____

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

a. ____

b. ____

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

____

____

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

____ Fresno ____ Visalia ____ Modesto ____ Sacramento ____ Bakersfield

____ Other (please provide) ________________________

6. Additional comments

____

____

____