

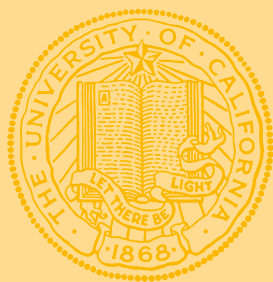
# California Agriculture



*100 Years of  
Science and Service*

**Also:**  
Cost of Pierce's Disease  
to California





**University of California**  
Division of Agriculture and  
Natural Resources

## California Agriculture corrections

On page 222 of the October-December 2013 issue, the third author's name was misspelled. The correct name is Shrinivasa K. Upadhyaya.

On page 218 of the October-December 2013 issue, the soil temperatures for the fall field trials were listed incorrectly. The sentence should read, "According to CIMIS data (Station 39, at Parlier), soil temperatures averaged 63.6°F, 73.9°F and 72.8°F during the fall 2009, summer 2010 and fall 2010 field trials, respectively."

*California Agriculture* is a quarterly, peer-reviewed journal reporting research and reviews, published by the University of California Agriculture and Natural Resources (ANR). The first issue appeared in 1946, making *California Agriculture* one of the oldest, continuously published, land-grant university research journals in the country. There are about 15,000 print subscribers, and the electronic journal logs about 5 million page views annually.

**Mission and audience.** *California Agriculture* publishes refereed original research in a form accessible to a well-educated audience. In the last readership survey, 33% worked in agriculture, 31% were university faculty or research scientists, and 19% worked in government agencies or were elected office holders.

**Electronic version of record.** In July 2011, the electronic journal became the version of record; it includes printed and electronic-only articles. When citing or indexing articles, use the electronic publication date.

**Indexing.** The journal is indexed by AGRICOLA, Current Contents (Thomson ISI's Agriculture, Biology and Environmental Sciences and the SCIE databases), Commonwealth Agricultural Bureau (CAB), EBSCO (Academic Search Complete), Gale (Academic OneFile), Proquest and others, including open-access databases. It has high visibility on Google and Google Scholar searches. All peer-reviewed articles are posted to the ANR and California Digital Library eScholarship repositories.

**Authors and reviewers.** Authors are primarily but not exclusively from ANR; in 2010 and 2011, 23% were based at other UC campuses, or other universities and research institutions. In 2010 and 2011, 33% and 40% (respectively) of reviewers came from universities, research institutions or agencies outside ANR.

**Rejection rate.** The rejection rate has averaged 34% in the last 3 years. In addition, associate editors and staff may send back manuscripts for revision prior to peer review.

**Peer-review policies.** All manuscripts submitted for publication in *California Agriculture* undergo double-blind, anonymous peer review. Each submission is forwarded to the appropriate associate editor for evaluation, who then nominates three qualified reviewers. If the first two reviews are affirmative, the article is accepted. If one is negative, the manuscript is sent to the third reviewer. The associate editor makes the final decision, in consultation with the managing and executive editors.

**Editing.** After peer review and acceptance, all manuscripts are extensively edited by the *California Agriculture* staff to ensure readability for an educated lay audience and multidisciplinary academics.

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**COVER:** This year marks the 100th anniversary of Cooperative Extension (CE), a national system linking land-grant universities with the communities they serve. In California, UC Cooperative Extension (UCCE) advisors provide practical, research-based solutions for problems from farm yields to community health. This issue includes a history of the federal legislation that created CE and UCCE's milestones over the last century (page 8), as well as current contributions that highlight its continued relevance (page 17). This then-and-now cover image shows UCCE wheat monitoring in Yolo County in 1930 (top) and grassland fieldwork today at Sierra Foothill Research and Extension Center (bottom). *Top photo courtesy of Yolo County Cooperative Extension archives; bottom photo by Elena Zhukova.*

## UCCE Centennial 100 Years of Science and Service

### Special section

#### 4 Editorial

ANR and Cooperative Extension touch people's lives  
*Napolitano*

#### 6 Outlook

Rebuilding for the next 100 years  
*Allen-Diaz*

#### 8 History

A century of science and service  
*Hayden-Smith and Surls*

#### 8 Timeline

Milestones of California's Cooperative Extension  
*Hayden-Smith et al.*

#### 16 Profile

Developing Northern California's first ranch marketing program  
*Palin Stein*

#### 17 Research news

UCCE's connection to the community continues  
*Meadows*



### Research and review articles

#### 20 Pierce's disease costs California \$104 million per year

*Tumber et al.*

Pierce's disease in California costs approximately \$104 million annually in lost production, vine replacement and public disease prevention programs.



#### 30 Seniors, and their food handlers and caregivers, need food safety and nutrition education

*Blackburn et al.*

Increasing numbers of seniors are at risk for foodborne illness. Make Food Safe for Seniors research shows a need for new curricula.



#### 38 Survey of rice storage facilities identifies research and education needs

*Espino et al.*

IPM techniques are widely used, but improvements are possible, such as in monitoring grain temperature and identifying pests.





## ANR and Cooperative Extension touch people's lives

During my first months as president of the University of California, I traveled around the state, educating myself on the workings and wonders of the UC system. One of my goals was to learn how the university serves the people of California and what we can do to enhance that public service.



**Janet Napolitano**  
President, University of California

At every stop, I saw outstanding examples of the ways UC enriches the lives, and livelihoods, of Californians. I visited labs where they're mapping the human brain, developing new battery technologies for electric and hybrid cars and studying ways to eradicate malaria. I was impressed with how UC's research discoveries not only drive the state's economy but also create opportunities for people who live far beyond California's borders. I developed a motto to capture the essence of what UC does: "Teaching for California, researching for the world."

UC's Division of Agriculture and Natural Resources (ANR) has its own mantra: "California roots, global reach." They both promote the same principle — we are dedicated to serving California and that service has impacts throughout the world.

One of the most profound ways in which UC touches people's lives is through the work of ANR and Cooperative Extension. Whether you are a backyard gardener or a major grower in the Central Valley, a

devotee of the California food and wine revolution or someone who simply strives to put nutritional meals on the table, chances are you have benefited from ANR, its research stations and the thousands of Cooperative Extension staff operating throughout the state.

### Moving forward

I am proud to be a part of this great enterprise of public service, especially during the centennial year of the founding of the national Cooperative Extension system. As our nation celebrates this milestone, it is an appropriate time to honor the history of UC's agricultural roots and to move forward with new ways of serving California.

To that end, I am making a change that will accomplish both at once. Historically, the ANR vice president reported directly to the UC president, just as the campus chancellors do. In recent years, the division was put under the umbrella of the Office of the Provost. It is time to restore ANR to its traditional place in the administrative structure of the university. Accordingly, ANR will once again report directly to the president. I believe this change properly reflects the importance of the work ANR does for the UC system and the state of California. It will ensure that agricultural issues remain front and center to the work of the University of California and will allow me to stay in better touch with the agricultural community.

### Deep roots

As a land-grant university, UC has always had a mandate to educate people in the latest agricultural methods. From the earliest days of the university, that was part of our mission.

When the Smith-Lever Act of 1914 created the national Cooperative Extension system, UC's mission expanded. The name Cooperative Extension itself embodies what that mission was intended to be and what it has evolved into.

"Extension" in this sense means reaching out and sharing the scientific knowledge of the university with the public. "Cooperative" is the key concept that makes these endeavors successful. With federal support, UC Cooperative Extension (UCCE) thrives as a partnership of growers, ranchers, state and local government and a committed community of ANR scientists, educators and employees. Together, this partnership has built California agriculture into a \$45 billion industry.

In celebration of the 100th anniversary of Cooperative Extension, this issue of *California Agriculture* highlights some of the many UCCE







# Rebuilding for the next 100 years

Barbara Allen-Diaz  
Vice President  
Division of Agriculture and Natural Resources  
University of California

In 2014 our nation commemorates the 100th anniversary of the founding of Cooperative Extension. For the University of California's Division of Agriculture and Natural Resources (ANR), this is both a year for celebration and for renewal.

As California's land-grant research university, UC, in 1914, was given the task of building the Extension system that the Smith-Lever Act envisioned would propel U.S. agriculture into the modern era. UC ANR embraced that vision with a prophetic belief that scientific knowledge could, indeed, transform California into the world's most successful agricultural producer.

For 100 years, UC Cooperative Extension has served as ANR's "community ambassador," delivering research and education programs in every California county. During this centennial year, we have much to celebrate, thanks to our storied history and the 1,350 dedicated individuals who make UC Cooperative Extension and all of ANR thrive.

Today, we operate nine Research and Extension Centers, 60 county offices and three administrative centers, with more than 11,000 acres, 320 Extension researchers and 650 campus-based academics devoted to sustaining and improving California's agricultural and natural resources.

Through this vast statewide network, ANR delivers practical, science-based information to California growers, ranchers, decision makers and, perhaps most importantly, the people of California.

Through our partnerships with the agricultural community; state, local and federal agencies; and the California State University, we address some of the most pressing problems of our day, including

- researching how to make safe, affordable food available to the world's 7 billion people;
- protecting scarce natural resources;
- building healthy, prosperous communities; and
- educating our future leaders to meet these and tomorrow's challenges.

In many ways ANR functions as UC's 11th campus. We don't grant degrees, but we educate more than 150,000 California young people every year in the California 4-H Youth Development Program. One of the original Cooperative Extension programs, 4-H teaches science, engineering, nutrition, ecology and good citizenship. By participating in 4-H, young people increase their likelihood of graduating from college fivefold.

ANR doesn't operate medical centers, but we work every day to fight childhood obesity and poor nutrition. Our Extension nutrition programs reach more than 222,000 adults and children in 33 counties.

Through UC Cooperative Extension's efforts, over the past three decades California's milk production has increased 44%; its processing tomato yields have increased 69% and almond yields have risen by 122%.

Using ANR-developed technology, California growers save 100,000 acre feet of water a year.

When invasive pests like the Asian citrus psyllid attack crops, ANR fights back with scientific advances in pest management and ongoing research to eradicate the threat.

Even in times of severe budget cutbacks, ANR consistently fulfills its public service responsibilities. The university and ANR have suffered through chronic funding declines that have threatened the quality of our programs and ability to serve the state. Now that California's finances are improving, we must focus on renewal.

Among my highest priorities as vice president is to rebuild the academic footprint of UC Cooperative Extension. To sustain UC's credibility with the people it was created to serve, we must continue to replenish our ranks (see next page) and revitalize programs trimmed during lean budget years.

We also must forge new public-private partnerships and strengthen the ones we have to attract diversified funding sources to our programs.

And we must build collaborations within the UC campuses to take advantage of the multidisciplinary nature of transformative research.

These are some of the challenges that keep me awake at night. We must accomplish these goals and more if UC Cooperative Extension and all of ANR are to contribute another 100 years to the health and vibrancy of the California we all treasure.

For 100 years, UC Cooperative Extension has served as ANR's "community ambassador."



UC ANR researcher checking codling moth trap in a walnut tree at sunrise

## Replenishing ANR's Cooperative Extension academic ranks

The following academic personnel have joined UC ANR since July 2012.

### **Oli Bachie**

Advisor; Imperial, Riverside and San Diego counties

### **Rob Bennaton**

Advisor; Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties  
Director; Alameda and Contra Costa counties

### **Dustin Blakey**

Advisor and Director; Inyo and Mono counties

### **Virginia Bolshakova**

Advisor and Director; San Francisco and San Mateo counties  
Director; Elkus Ranch

### **Gurreet Brar**

Advisor; Fresno and Madera counties

### **Lyn (Rebecca) Brock**

Academic Coordinator; UC Nutrition Education Professional Development Program

### **Sandra Derby**

Academic Coordinator; California Project Learning Tree Program

### **Ryan DeSantis**

Advisor; Shasta, Siskiyou and Trinity counties

### **Dorina M. Espinoza**

Advisor; Del Norte, Humboldt, Lake and Mendocino counties

### **Jim Farrar**

Director; Western IPM Center

### **Julie Finzel**

Advisor; Kern, Kings and Tulare counties

### **Lisa Fischer**

Associate Director; Research and Extension Center System

### **Missy Gable**

Director; Statewide Master Gardener Program

### **Latonya Harris**

Academic Coordinator; Youth, Families and Communities Statewide Program

### **Russell Hill**

Advisor; Madera, Mariposa, Merced and Stanislaus counties

### **Anne Iaccopucci**

Academic Coordinator; 4-H Healthy Living Initiative

### **Jeremy James**

Specialist and Director; Sierra Foothill Research and Extension Center

### **Shimat V. Joseph**

Advisor; Monterey, San Benito and Santa Cruz counties

### **Susie Kocher**

Advisor; Amador, Calaveras, El Dorado and Tuolumne counties

### **Igor Lacan**

Advisor; Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties

### **Michelle Leinfelder-Miles**

Advisor; Contra Costa, Sacramento, San Joaquin, Solano and Yolo counties

### **Dani Lightle**

Advisor; Glenn County

### **Bruce Linquist**

Specialist; Department of Plant Sciences, UC Davis

### **Mark Lundy**

Advisor; Colusa, Sutter and Yuba Counties

### **Fadzayi Mashiri**

Advisor; Madera, Mariposa and Merced counties  
Director; Mariposa County

### **JoLynn Miller**

Advisor; Amador, Calaveras, El Dorado and Tuolumne counties

### **Maurice Pitesky**

Specialist; Department of Population Health and Reproduction, UC Davis School of Veterinary Medicine

### **Lorrene Ritchie**

Specialist and Director; Nutrition Policy Institute

### **Drusilla Rosales**

Advisor; Los Angeles and Orange counties

### **Samuel Sandoval Solis**

Specialist and Assistant Professor; Department of Land, Air and Water Resources, UC Davis

### **Noelia Silva-del-Rio**

Specialist; Department of Population Health and Reproduction, UC Davis School of Veterinary Medicine

### **Christopher Smith**

Director; Ventura County  
Director; Hansen Research and Extension Center

### **Martin Smith**

Specialist; Department of Human Ecology and UC Davis School of Veterinary Medicine

### **Katherine Soule**

Advisor; San Luis Obispo and Santa Barbara counties

### **Alex Souza**

Advisor; Kern and Tulare counties

### **Jeffery Stackhouse**

Advisor; Del Norte and Humboldt counties

### **Kristen Stenger**

Advisor; Fresno and Madera counties

### **Andrew Sutherland**

Advisor; Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties

### **Kris Tollerup**

Advisor; Kearney Agricultural Research and Extension Center

### **Julia Van Soelen Kim**

Advisor; Marin, Mendocino, Napa and Sonoma counties

### **Guangyao "Sam" Wang**

Specialist and Director; Desert Research and Extension Center

## A century of science and service

Rose Hayden-Smith, UC Cooperative Extension 4-H Youth, Family and Community Development Advisor, Ventura County

Rachel Surls, UC Cooperative Extension Sustainable Food Systems Advisor, Los Angeles County

**O**n a warm Friday, May 8, 1914, in Washington D.C., two pieces of new legislation awaited President Woodrow Wilson's signature: a proclamation establishing the second Sunday each May as Mother's Day, and the Smith-Lever Act. The honoring of mothers dominated the news that day, but Wilson recognized the importance of the Smith-Lever Act, calling it "one of the most significant and far-reaching measures for the education of adults ever adopted by government."

Sponsored by Sen. Hoke K. Smith and Rep. Asbury F. Lever, the bill was the result of national efforts to create a new educational model for U.S. agriculture. At that time, land-grant universities ran farmers institutes and short courses taught by lecturers, and the U.S. Department of Agriculture (USDA) offered its own form of Extension work that focused on pest control field demonstrations in the South and farm

management in the North. Yet there was no consistent or efficient way to deliver important knowledge from the university campuses to the communities that needed it. Passage of Smith-Lever launched a century of innovation in U.S. education that continues to this day. In California, the educational model born out of the legislation is UC Cooperative Extension. For 100 years this statewide network of UC researchers and educators has developed and provided science-based information to solve locally relevant challenges in the areas of economics, agriculture, natural resources, youth development and nutrition.

### Progressive roots

Agriculture has always been vital to America. In 1860, at the outset of the Civil War, farmers made up 58% of the U.S. labor force. It was that demographic that created the impetus behind the 1862 Morrill Act, which gave each state a grant of land to establish a college that would teach practical subjects such as agriculture and engineering (see *California Agriculture*, April-June 2012, pg. 42). A key role of those

*Continued on page 10*

## California milestones



Library of Congress

**1862**

President Lincoln signs Morrill Act, authorizing development of agricultural "land-grant" colleges in each state

**1887**

Hatch Act establishes federal funding for agricultural research in state land-grant colleges

**1913**

Andrew Hansen Christiansen named California's first Extension farm advisor, placed in Humboldt County

**1912**

UC agricultural clubs formed in Ferndale and Fortuna; these early clubs evolved into today's 4-H program



**1919**

B.H. Crocheron recruited to direct state's Agricultural Extension Service, which he does for next 35 years

**1918**

First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

**1900**

**1880**

**1860**

**1868**

University of California founded to teach "agriculture, mining and the mechanical arts"



The Bancroft Library, UC Berkeley

**1914**

Congress passes the Smith-Lever Act, making federal funds available for extension work



Library of Congress

**1915**

UC Agricultural Extension Service (later renamed "Cooperative Extension") appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

**1917**

Emergency war appropriations provide growth for UC Agricultural Extension as "food for victory" becomes national priority



## The presidential roots of Cooperative Extension

Over the course of more than half a century, Presidents Abraham Lincoln and Woodrow Wilson signed bookend legislation that created the land-grant institutions and Cooperative Extension. Despite very different backgrounds and political ideologies, they reached very similar conclusions about the vital nature of agricultural education to U.S. prosperity.

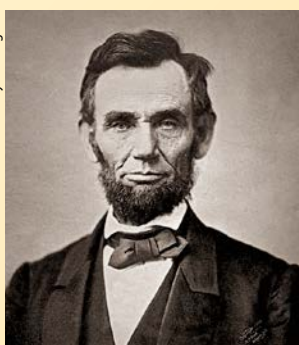
President Lincoln, a Republican, who signed into law the Morrill Act, creating the nation's system of public higher education and land-grant institutions, and President Wilson, who signed the Smith-Lever Act, which created the Cooperative Extension service, were

both shaped by the American Civil War. Lincoln experienced the war firsthand, serving as president of the United States when the South seceded from the Union, and brought the nation intact, although battered, through 4 grueling years of war. Lincoln was born and raised on a farm, and his lack of formal education influenced his ideas about educational access for Americans. Life on the farm also influenced his ideas about the importance of

creating a federal-level agency (the USDA, what Lincoln termed "the people's department") to manage agriculture, of opening up land to settlers by means of the Homestead Act, and of creating a transnational railroad system to promote commerce.

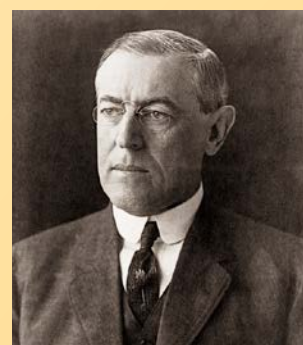
A Democrat, Wilson was born in Virginia. At the end of the Civil War, when he was only 8 years old, he watched the former Confederate president, Jefferson Davis, brought through his community in chains. As a youth he saw how local farmers struggled after the war. He attended elite educational institutions, including the University of Virginia and the College of New Jersey (later renamed Princeton University), and received a doctorate from Johns Hopkins University. Wilson was the first president to ride to his inauguration in an automobile. He never forgot his firsthand observations of the economic challenges Southern farmers faced in the post-Civil War era; these experiences strongly influenced his ideas about scientific agriculture and the importance of Extension education.

Library of Congress



President Abraham Lincoln

Library of Congress



President Woodrow Wilson



1920

Crocheron establishes week-long traveling conferences where caravans of farm advisors and Farm Bureau representatives travel for hundreds of miles viewing selected farms.

Farm Bureau centers established in more than 500 rural communities



1922

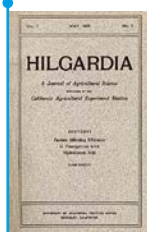
Growers begin acquiring tractors; UC Extension holds one-week schools in 12 counties teaching growers how to adjust and repair their new machinery

1924

Extension workers help bring an outbreak of foot and mouth disease under control

1925

*Hilgardia*, a monographic series of agricultural science, begins



1929

Extension provides emergency assistance when St. Francis Dam break inundates portions of Ventura and Los Angeles counties

Extension Director Crocheron embarks on fact-finding tour in Asia to investigate potential markets for California specialty crops; his outlook is not optimistic

1927

Extension academics begin specializing in poultry, dairy, citrus, walnuts, agricultural engineering, etc.

1920

1921

Volunteer leader concept implemented for high school boys' and girls' agricultural clubs organized by farm advisors, forming the basic structure and philosophy for today's 4-H Youth Development Program

1923

Extension completes first decade with 40 farm advisors, 33 assistant farm advisors and 21 home demonstration agents in county offices

1926

First Agricultural Extension circulars published



1928

"4-H" appears for the first time in California reports on youth work

## UC Cooperative Extension history

colleges was to develop knowledge that would help farmers produce enough food and fiber to meet the needs of a growing nation.

In 1887, the Hatch Act was passed to further this mission; it provided land-grant colleges with funds to develop agricultural experiment stations, where research was conducted. Passage of the Adams Act in 1906 doubled funding to the research stations, while requiring a new funding commitment from state sources. The infusion of federal and state capital facilitated agricultural research, education and innovation, and generated increasing interest in U.S. agriculture among policymakers concerned about food security and increasing economic opportunities.

Five years of debate had preceded the Smith-Lever legislation. The McLaughlin Bill, proposed in 1909, left no clear role in Extension work for the USDA. Opponents of that bill were familiar with the work of early Extension educator Seaman A. Knapp and argued for his model, which emphasized demonstration work on farms. The final Smith-Lever legislation was a compromise, facilitated by USDA Secretary David Houston, that proposed a single Extension service from the USDA's agricultural

Extension system and land-grant education, and created a federal, state and county funding formula for it that persists to this day.

The intent of the Smith-Lever Act, like earlier agricultural legislation, was broadly democratizing. Initially, Extension focused on improving and reforming rural life, partly in response to the findings of the Country Life Commission, created by President Theodore Roosevelt in 1908. The Smith-Lever Act was rooted in the Progressive philosophy of helping people help themselves, a philosophy that continues to inform Cooperative Extension's work today, and it demonstrated Progressive Era beliefs in the value of public-private partnerships and shared funding models.

In the case of Cooperative Extension, the model included federal (USDA), state (land-grant universities) and local support (county funding, and the organization of a local Farm Bureau to sponsor the work). This relationship with the Farm Bureau was a vital component in Cooperative Extension's formation and identity; their growth and partnership has been

*Continued on page 12*



**1930**

Focus turns to practical application of science to agriculture, with progress on soil fertility and new dusts and sprays to control crop diseases

**1934**

Severe drought hits California: 18 California counties declared emergency areas eligible for federal funds; farm advisors serve as government agents in purchasing livestock in the hardest-hit areas

**1934**

Extension tapped to help federal government implement and administer Agricultural Adjustment Administration programs to help growers stabilize their incomes

**1938**

Federal-state agreements establish pilot land-use planning program in U.S. counties; UC Extension monitors programs in Riverside, Kern, Sonoma and Yuba counties

**1937**

George B. Alcorn joins Extension as agricultural economist; he will become third director of California Agricultural Extension Service in 1956



**1943**

Extension asked to administer Emergency Farm Labor Project to assure adequate supply of workers for wartime agricultural production

**1942**

In response to Pearl Harbor, Extension agents organize Emergency Farm Fire Protection Project, forming more than 2,000 volunteer fire companies in 42 counties to thwart possible incendiary attacks

Director Crocheron organizes California Minute Men rural militia; 20,000 men sign up through county Extension offices to serve on reserve duty

**1940**

**1940**

Farm advisors and home demonstration agents lead wartime committees, conduct war bond campaigns and organize state militia that recruits more than 23,000 volunteers

**1941**

Victory gardens and rural fire protection become important Extension topics



**1930**

**1932**  
"Cal-Approved" seed program begins to ensure quality seed for standard and improved varieties

**1935**  
With encouragement from a UC Extension forestry specialist, 2,000 miles of windbreak planted to effectively protect Southern California citrus districts



**1936**

Congress approves Soil Conservation and Domestic Allotment Act to conserve soil and prevent erosion; Extension agents given responsibility of carrying out organizing work



## A profile in excellence

In the late 1930s and early 1940s, a young UC-trained agronomist named Milton D. Miller worked as an assistant farm advisor in the UC Cooperative Extension office in Ventura County. When the United States entered World War II, Miller enlisted in the U.S. Army as a captain and was deployed to the Pacific theatre. He worked for the U.S. Subsistence Procurement Branch in Australia, where he helped farmers transition from hand-hoeing vegetable fields to using mechanical weeders, as part of the effort to boost Allied war-time food production. An engaging writer, Miller corresponded regularly with the Cooperative Extension staff in Ventura, exchanging news and thanking them for gift packages that included fruitcake, handkerchiefs and tobacco.

After the war ended, Miller returned to service with UC Cooperative Extension, working as an Extension specialist from what eventually became the UC Davis campus. His notable career spanned more than 50 years, and his work in rice, cereal and oilseed crops, and food procurement had local, state, national and international impacts. Producers here and all over the world benefited from his research on rapidly developing technologies to improve practices and increase production.



Milton Miller (right) in a Tasmanian carrot seed production field during World War II, 1944.

Special Collections, General Library, UC Davis



**1945**

In response to newly formed Forest Service grazing restrictions, Extension advisors help ranchers determine most efficient locations and methods to feed cattle

**1948**

Extension Director Crocheron dies suddenly, ending an era; acting director Chester Rubel writes "... a deep understanding of rural problems, a genius for organization, and a devotion to agriculture and to rural people ... made [Crocheron] an outstanding leader. ... The foundations which he laid are sound and enduring ... His work will go on."



**1956**

UC Davis scientists and Extension farm advisors develop tomato varieties around state, identifying three new hybrids with superior yields

**1950**

Extension reorganizes to better cope with scientific and technical advances and with California's rapidly increasing population; home demonstration agents become home advisors; county director positions created to coordinate local farm and home advisor programs

New specialist positions added in range management, ornamental horticulture, subtropical horticulture, plant pathology, vegetable crops, deciduous fruits and nuts, agricultural engineering, marketing, extension education, 4-H, home economics, youth counseling, apiculture, biometrics, climatology, crops processing, forest products, nematology, parasitology, enology, pesticide safety, consumer marketing, wildlife management, public affairs, radio-TV, dairy products and soil and water salinity



**1957**

Extension farm advisors work on improving irrigation efficiency by applying water based on specific soils and crop needs

**1955**

Extension staff totals 549, more than double 1940's Extension workers

**1950**

**1947**

Seventy-eight new Extension agents hired

**1953**

Extension researchers study air pollution damage to various crops in Los Angeles Basin and San Francisco Bay Area

**1954**

UC Extension specialists coordinate with USDA to develop new shade structures for livestock in hot weather



**1958**

UC Extension entomologists release guidelines for growers on minimizing effects of pesticides on bees

**1959**

Extension agricultural economists study challenges and opportunities in California's rural-urban transition

**1946**

Sixty new Extension appointments made  
*California Agriculture* journal begins publishing



## UC Cooperative Extension history

**Passage of Smith-Lever launched a century of innovation in U.S. education. In California, the educational model born out of the legislation is UC Cooperative Extension.**

extraordinarily successful in advancing American agriculture. Local farmers and Cooperative Extension shared ownership in this shared model and the knowledge produced, and they still do.

What is difficult to comprehend today, 100 years later, is the sense of urgency surrounding the need

to improve U.S. agriculture in 1914. The nation's agricultural sector faced difficulties in a number of areas, including production, yield, labor sources and distribution. Rural areas were depopulating, and the number of farmers was dropping. At the same time, an inexpensive, secure and ordered food supply was believed essential for civil order and national progress.

1914 was a momentous year. The Panama Canal opened. Ford Motor Company established an 8-hour workday and increased wages. The National Guard fired upon striking miners in Colorado. Racial tensions ran high, as did tensions between rural and urban

populations. U.S. naval forces landed and occupied Veracruz, Mexico, bringing the two countries to the brink of war. By August, World War I had started, and U.S. agricultural products were sorely needed to feed and support our allies. Efficient agriculture backed by scientific solutions became a national priority.

### Partners in California

Even before passage of the Smith-Lever Act in 1914, efforts were already under way to create an agricultural Extension system in California, building on the success of the state's land-grant college, the University of California. The first UC campus, at Berkeley, had agriculture as an important early focus. In 1907, a university research farm was opened in Davisville to serve Berkeley students. That site grew into a new campus, UC Davis. The same year, UC established the Citrus Experiment Station in Riverside, which was instrumental in helping California emerge as the nation's premier citrus producer, creating a second Gold Rush of sorts, as thousands flocked to the Golden State to capitalize on the opportunities that the state's agricultural and natural resource abundance

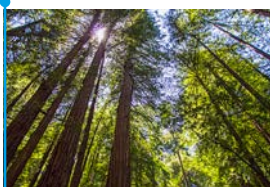
*Continued on page 14*

**1960**

Extension efforts on advancing production agriculture improve farm productivity and mechanization

Home economics program reorganized as Family and Consumer Sciences

4-H programs developed in urban, low-income areas



**1962**

Experiment Station researchers and specialists study how to protect state's redwood trees from soil compaction and other damage from recreation, logging and development

**1964**

50th anniversary of Smith-Lever Act; UC Extension has 532 farm and home advisors and specialists in 50 subject areas



**1965**

Extension irrigation specialist and Sacramento County farm advisor encourage nurseries to use plastic tubes with electric timer to irrigate containers, rather than overhead sprinklers

**1967**

Extension farm advisors work with UCD's Department of Vegetable Crops to develop new varieties of peppers resistant to tobacco mosaic virus



**1970**

Extension programs begin to take an international perspective, reflecting concerns about world food supply

Programs established in community development, farm personnel management, integrated pest management (IPM) and marine fisheries

**1971**

Extension farm advisors, specialists and Agriculture Experiment Station faculty boost Central Coast production by conducting mechanical harvesting trials for Ventura County citrus, demonstrating chemical inhibition of avocado top regrowth and assessing lettuce response to soil fumigation for nematode control

**1960**



**1961**

UC's pioneering biocontrol efforts well under way; scientists release imported parasitic wasps to combat specific citrus pests

**1963**

Farm advisors work with rice growers in Butte, Colusa, Glenn, San Joaquin, Sacramento, Sutter, Yolo and Yuba counties on fertilizer efficiency

**1966**

Extension entomologists and Fresno County farm advisors study impact of insecticides on beneficial insects in cotton fields, part of UC's work on pest control methods that utilize beneficial insects, mites and spiders



**1970**

**1969**

Expanded Food and Nutrition Education Program (EFNEP) developed to reach low-income families

**1972**

UC conducts drip irrigation experiments on San Diego County avocados

**1973**

In response to environmental concerns, UC works with Santa Clara County's canning industry on using cannery wastes as soil amendment



## May 8, 2014: Day of citizen science

The real strength of UC Cooperative Extension is its ability to facilitate and build networks of knowledge that include scientists, producers, community members and practitioners. We learn together. This engaging process by everyone, not just the professional experts, has been an important part of our national history. Before the formalization of higher education and the specialization of scientific disciplines, much of our scientific knowledge was gathered by citizens through trial and error and then passed along to others. Presidents George Washington and Thomas Jefferson shared their knowledge of agricultural science in their correspondence and at agricultural fairs and meetings. Benjamin Franklin published scientific discoveries that provided a foundation for future technological innovation. John Bartram, a self-trained botanist and explorer, presented his plant knowledge in Philadelphia by making a garden, considered by many to be the nation's first significant botanical collection.

Citizen science is gaining traction in contemporary communities. Also known as crowd science, crowd-sourced science, networked science or public participation in science research, citizen science is a form of participatory scientific research conducted, in whole or in part, by amateur or nonprofessional scientists. Through citizen science projects, community members engage and participate in

scientific research by contributing their own knowledge, observations and intellectual efforts, often using social, web-based technologies or mobile applications.

On Thursday, May 8, 2014, the Division of Agriculture and Natural Resources (UC ANR) will celebrate the 100th birthday of UC Cooperative Extension with a citizen science event – the Day of Science and Service. UC Cooperative Extension will crowd-source data for citizen science projects about water, food and pollinators. Every Californian is invited to participate in this free celebration of science.

UC ANR is developing data collection maps, and participants will be able to access them through their computers or smartphones and add their data directly to the maps. After adding data, they will be

taken to a landing page with more information about why the questions are important and links to additional research in these three areas. After the Day of Science and Service, the data will be tabulated and analyzed, and the results will be shared with participants.

For more information about participating, visit <http://Beascientist.ucanr.edu>.

—Marissa Palin Stein



1976

UC research indicates that EFNEP improves dietary practices of low-income populations

1977

UC Small Farm Program established to focus on specialized needs of small-scale and limited-resource growers

1980

From 600 pages of oral history gathered by UC researchers, UCCE studies how technology has changed farms and farm families



1980

UC announces the release of six new strawberry varieties

1982

Peripheral Canal referendum fails; UCCE praised for providing objective water policy information to public

1986

UC begins two environmentally oriented programs: Sustainable Agriculture Research and Education Program, to help California growers practice sustainable production and marketing systems; and Integrated Hardwood Range Management Program, to study problems facing oak trees and other hardwoods

1980

1974

UC changes name of Agriculture Extension Service to UC Cooperative Extension (UCCE) to reflect its broadening social and economic purview



UC explores impacts of significant air pollution on Southern California leafy vegetables and on San Joaquin Valley cotton production

1979

UC Statewide Integrated Pest Management Program formed to accelerate research and education on production alternatives that use fewer chemicals

1981

UC survey of agricultural college graduates shows women have not yet broken barriers in employment, salaries and status in agriculture  
UC hires its first affirmative action officer to encourage more women and minorities to seek careers in CE



## UC Cooperative Extension history

seemed to ensure. The experiment station at Riverside served as the foundation for the UC Riverside campus.

By the time the Smith-Lever Act became law, new knowledge and technologies developed by UC scientists were critical to the growth of farming and allied industries around the state. UC agriculture faculty were already offering short courses at farmers institutes, but farmers were clamoring for more and eager to have a Cooperative Extension educator, known as a farm advisor, assigned to their community.

Anticipating passage of Smith-Lever, UC officials required each county government that wanted to participate in a Cooperative Extension partnership to allocate funding to help support Extension work in that community. Additionally, it was required that a group of farmers in participating counties organize into a Farm Bureau to help guide the Cooperative Extension farm advisor on the issues of local agriculture. (These grassroots groups later evolved into the California Farm Bureau Federation.) The first California county to sign up, Humboldt County, had its farm advisor in place by July 1913, before passage of the federal legislation. Seven more counties came on board in 1914, and in the following years 41 of the 58 California counties secured Cooperative Extension farm advisors.

Cooperative Extension played a critical role on California's home front during World War I, helping farmers to grow enough wheat and other crops to meet expanded wartime needs. Extension's value was quickly established as farmers came to rely on having an expert close at hand who was familiar with local conditions and crops. In addition to addressing the needs of farmers, Cooperative Extension soon expanded to provide educational opportunities for their families. Female extension agents — home advisors — were hired; they taught food preservation and nutrition and ran other programs for rural women and activities for local youth. This new generation of college-educated female home economists increased the contact and interchange between urban and rural communities, especially on social and domestic issues. Cooperative Extension also reached thousands of young people who would learn about food production, animal husbandry, cooking, science and more through participation in 4-H clubs.

### UC Cooperative Extension today

UC Cooperative Extension, part of UC Division of Agriculture and Natural Resources (UC ANR), is comprised today of 320 locally based Cooperative Extension advisors, 650 campus-based Cooperative Extension specialists, 60 county offices throughout the state, and nine research and extension centers. It has

**1988**

UCCE reorganized, making campus-based specialists integral part of academic departments



**1989**

California 4-H club members number about 76,000; more than 40% live in large cities or suburbs and 55% are girls

**1992**

Experts from UCCE analyze economic impact of sweet potato whitefly in Imperial Valley



**1993**

UCCE helps small-scale growers by providing workshops for Southeast Asian immigrant growers in Central Valley

**1996**

UCCE begins using World Wide Web and email to conduct outreach

Spanish-language UCCE specialist begins using radio to teach nutrition to Latino families



**2001**

UC scientists develop integrated approach to managing sudden oak death, a disease that has killed millions of oak trees

**1999**

UCCE team documents significant benefits from agritourism to growers and communities in San Diego and other metropolitan counties

**1990**

**1990**

Money Talks program developed by UCCE home economists to help low-income families improve their financial situations

**1991**

UCCE specialists share potential impacts of fair trade agreements on popular commodities

**1994**

Study by UCCE scientists documents trend of growers using more sustainable farming practices



**1995**

With help from UCCE researchers, almond growers in Merced County reduce pesticide use

**2000**

**2000**

Study by UCCE researchers finds that school gardens teach children healthier eating habits



**1998**

In response to dust pollution concerns, UCCE scientists collaborate to stabilize soil and reduce windblown dust in Antelope Valley



rural roots, but as the nation has grown and communities have changed, Cooperative Extension has evolved, adapting programs and developing new ones to meet the needs of rural and nonrural audiences. Since the 1960s, the Expanded Food and Nutrition Education Program (EFNEP) has provided free nutrition education classes in urban communities. Thousands of urban and suburban residents have benefited from the Master Gardener program, which offers workshops and advice to home, community and school gardeners; currently, more than 5,400 master gardener volunteers serve California communities. The Master Food Preserver program teaches Californians to safely preserve the healthy foods we produce. A new Master Naturalist program is training volunteers to help communities respond to complex issues in sustainable natural ecosystems; observations by volunteers in the community are recorded using mobile technologies so the data can be studied by scientists, who then respond to and help solve community problems.

All of Cooperative Extension's activities are grounded in university research and developed in partnership with local communities. After a century of service, UC Cooperative Extension continues to deliver practical, trusted, science-based solutions to Californians.

## Suggested reading

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- Scheuring AF. 1995. *Science and Service: A History of the Land-Grant University and Agriculture in California*. Oakland, CA: UC ANR Publications.
- Stage S, Vincente VB. 1997. *Rethinking Home Economics: Women and the History of a Profession*. Ithaca, NY: Cornell University Press.
- Surls R, Hayden-Smith R. 2013. UC Cooperative Extension's collaborations grow with the centuries. *Calif Agr* 67(3):118. doi:10.3733/ca.v067n03p118.



2005

Kearney Agricultural Research and Extension Center celebrates 40 years partnering with UCCE on research

2007

UCCE develops and tests IPM program for cut roses, the largest component of California's cut-flower industry



2013

UC ANR holds Global Food Systems Forum, attracting viewers from more than 70 countries

2014

UCCE celebrates 100 years of bringing science and service to California communities

2010

Four UC ANR strategic initiatives established: Sustainable Food Systems, Healthy Families and Communities, Endemic and Invasive Pests and Diseases and Sustainable Natural Ecosystems

UCCE study finds Southern California nurseries adopting best practices for reducing water runoff from their facilities

2011

Strategic initiative for Water Quality, Quantity and Security established

Collaborative UCCE and UCD study on nitrate levels in groundwater released to State Water Board and governor

2010

2004

UCCE nutritional research finds link between food insecurity and obesity in Latino families



2006

UCCE study finds decreasing size of grape harvest baskets leads to healthier farm workers and fewer back problems

2008

Sonoma and Napa UCCE study biocontrol in vineyards as part of CE's work on making viticulture more sustainable

2009

UC ANR introduces its Strategic Vision through 2025

2012

UC ANR internal grants program funds research and extension education in new areas of biofuels and local food systems

—Rose Hayden-Smith, Rachel Surls and Marissa Palin Stein

## Developing Northern California's first ranch marketing program

California's El Dorado County was once part of a thriving commercial pear-growing region. In 1958, its growers produced more than 52,000 tons of pears on 3,400 acres. The local Placerville Fruit Growers Association, established in 1915, was a busy pear-packing cooperative. But in the late 1950s, pear decline disease invaded California and nearly destroyed nearly all of El Dorado's premium Bartlett pear orchards. By 1964, the county's production had dropped to 8,435 tons. Farmers were devastated, and their families at risk.

The late Dick Bethell was UC Cooperative Extension pomology advisor in El Dorado, San Luis Obispo, Santa Cruz and Sonoma counties but he lived in Placerville. He couldn't stand watching his community suffer, and he got to work restructuring El Dorado's entire growing industry. Bethell encouraged local growers to diversify into stone fruits, wine grapes, berries and, most of all, apples.

In the 1960s, after a visit to Oak Glen, a successful apple-growing region in Southern California's San Bernardino Mountains, Bethell and his partners envisioned a similar agritourism industry in El Dorado County, based on apple production. Bethell, grower Gene Bolster, agricultural commissioner Ed Delfino, and retired army officer

Bob Tuck formed the Apple Hill Growers Association, based on the Oak Glen model and its agritourism by-laws. The following summer, in 1964, they held their first Apple Hill picnic for the news media, and not long afterwards they recruited visitors at the California State Fair.

Today, the Apple Hill Growers Association has grown from 16 farmer members to over 55, and Apple Hill has the largest concentration of apple growers in all of California. Their efforts have paid off: Apple Hill has become a very popular tourist destination in Northern California. More than 750,000 visitors tour the area each year to visit you-pick farms; buy fresh apples and apple products; chop Christmas trees; eat lunch; and stop at a local brewery, spa and wineries.



Apple Hill has the largest concentration of apple growers in all of California. Above, Boa Vista Orchard in Placerville.



Jack Kelly Clark

More than 750,000 visitors tour the Apple Hill area each year to buy fresh apples and apple products.

Apples aren't the only crop El Dorado visitors now enjoy, and UCCE's Bethell had a hand in that as well. Once a thriving wine country, with early settlers supplying Gold Rush communities with spirits and fruit, El Dorado's wine grape industry suffered during Prohibition and from grape phylloxera.

In 1965, Bethell oversaw the planting of several wine grape test plots at various foothill elevations in the county. The wines produced from these plots were evaluated by the UC Davis Department of Enology, which confirmed the suitability of the region for quality wine grapes. The re-emerging industry grew from 6 acres to more than 2,000 acres of vines and 50 wineries during Bethell's tenure. The county was officially designated as an American Viticultural Area in 1983, and today, thanks to the early encouragement by Dick Bethell, El Dorado produces some of California's top wines and most beloved apples.

— Marissa Palin Stein



Will Suckow

Since the planting of wine grape test plots in 1965, the wine industry in El Dorado County has grown to more than 50 wineries and produces some of California's top wines. Above, Boeger Winery vineyard in Placerville.



## UCCE's connection to the community continues

### Introduction

**UC** Division of Agriculture and Natural Resources (ANR) research — on campuses, at research and extension centers and in Cooperative Extension offices throughout the state — focuses on critical issues in California's agriculture, natural resources, youth development and nutrition. Five strategic initiatives in UC ANR provide collaborative opportunities for addressing these issues: Endemic and Invasive Pests and Diseases; Healthy Families and Communities; Sustainable Food Systems; Sustainable Natural Ecosystems; and Water Quality, Quantity and Security. These initiatives look for new approaches, new resources and new partnerships within and outside UC to identify, communicate and solve these problems. The five Cooperative Extension projects highlighted in this article represent these five strategic initiatives.

Today, in its 100th year of service, UC Cooperative Extension (UCCE) is as connected to California communities as ever. UCCE advisors provide expertise and practical, science-based solutions on a wide range of subjects — from family health to food production to water quality to invasive pests — and have a keen understanding of local issues because they live and work in the communities they serve. The following are just a few examples of the many ways UCCE benefits Californians now.

### SUSTAINABLE FOOD SYSTEMS STRATEGIC INITIATIVE

#### Beginning growers and ranchers

**F**arming as a way of life is waning in Sonoma County, as agricultural land is converted to housing and the average age of growers nears 60 years. "We need to bring new farmers into the business," says Stephanie Larson, director of UCCE Sonoma County.

To do just that, she launched a Beginning Farmer and Rancher program with a 3-year grant from the United States Department of Agriculture (USDA) beginning in 2011. The program includes hands-on experience in production and business planning (including marketing, organic certification, permitting and regulations, and lending) as well as mentoring by local master growers and ranchers. "Farming is challenging," Larson says. "People can have a great idea but often fail due to the business end."

Just as importantly, participants get access to land. They can lease vacant county land, and can use a website that matches new growers and ranchers with private landowners who want to lease acreage. In addition, a training farm — known as an incubator farm — is in the works, which will help participants get started by, for example, providing shared equipment, mentoring, and a lower initial lease rate.

"We have folks who already have land and are hoping to reinvent and save their family farms, or who are switching careers to grow local food," says Linda Peterson, UCCE Beginning Farmer and Rancher program coordinator. About half of the 43 participants to date are minorities, women or low-income, and most are now working in the agricultural field. "They've increased production, started farms or are working on farms," she says. Their operations include local hard cider, dry-farmed tomatoes, sheep and goat cheese, and agricultural tourism.

Now, Larson and Peterson are integrating their Beginning Farmer and Rancher program into the sustainable agriculture program at Santa Rosa Junior College, which will ensure that the program continues long after the USDA grant is finished.

### HEALTHY FAMILIES AND COMMUNITIES STRATEGIC INITIATIVE

#### Eating Smart, Being Active

**M**ost of us know the basics of a healthy lifestyle — eat plenty of fruits and vegetables, exercise regularly, and so on — but knowing what to do to and



Beginning Farmer and Rancher (BFR) participant Kelly Osman tags the ear of a pregnant Black Angus cow, with help from Denner Ranch owner and BFR mentor Terry Lindley (front) and ranch hand Joey Howard (back).

actually doing it are far from the same thing. To help Californians make healthy choices that stick, UC ANR administers and UCCE delivers the federally funded Expanded Food and Nutrition Education Program (EFNEP) statewide.

As part of the program, UCCE nutrition educators teach adult classes with the *Eating Smart, Being Active* curriculum, which was developed by EFNEP and UCCE staff at UC Davis and Colorado State University. Used by Cooperative Extension nationwide, the curriculum consists of eight 1-hour classes that help people make healthy lifestyle choices. Sessions include “Get Moving!,” “Vary Your Veggies, Focus on Fruit,” and “Make Half Your Grains Whole.”

In 2013, this program reached more than 9,000 low-income families in California. “Half of participants now eat three or more servings of vegetables and two or more servings of fruit per day,” says Connie Schneider, director of UC ANR’s Youth, Families and Communities statewide program, which includes EFNEP. “This is a remarkable improvement.”

Juana Gonzalez of Colusa is a standout EFNEP graduate. She went from eating hardly any produce to enjoying two cups each of vegetables and fruit a day, and now seasons her food with herbs and spices instead of salt, and drinks water instead of soda. She also bumped up her daily exercise from less than half an hour to more than an hour. Her reward? Gonzalez has lost weight and no longer needs high blood pressure medication. “I feel better and, best of all, my teenage daughter is making healthy lifestyle changes with me,” she says.

Besides embracing her new lifestyle, Gonzalez inspires others to do the same. “Now Juana comes to the first class of my other sessions to say, ‘Look what this did for me,’” says Sonia Rodriguez, EFNEP nutrition educator at the Altami Learning Center in Colusa. “She’s a great advocate.”

### SUSTAINABLE NATURAL ECOSYSTEMS STRATEGIC INITIATIVE

#### Training conservation volunteers

Just an hour’s drive north of Los Angeles, the Tejon Ranch Conservancy was overwhelmed with requests to visit the 240,000 acres of oak woodland, desert, fir forest and chaparral that it manages. This range of habitats makes the ranch a hotspot of biological diversity, with big draws such as condors, pronghorn, mountain lions and stunning wildflower displays. “This is a huge piece of land that is really unique in California because there has been no intensive recreation — ranching can be more compatible with endangered species than a lot of people tromping around,” says Sabrina Drill, UCCE natural resources advisor in Los Angeles County. “Because this is still working land, all public access needs to be guided, and they couldn’t keep up with the demand.”

Drill is also co-director of UC ANR’s new California Naturalist Program, which partners with local organizations statewide to engage the public in the study and stewardship of California’s natural resources. This makes the program a perfect fit with the Tejon Ranch Conservancy. “They need help with monitoring and restoration projects, and with allowing the larger community to come and enjoy the land,” she says. “They thought they were going to have to develop their own



Tejon Ranch Conservancy volunteer Deonsa Taylor measures residual dry matter on rangeland, which will help manage grazing on this working cattle ranch.

curriculum so they were excited to have a UC-vetted, science-based stewardship education program already available.”

The curriculum includes 40 hours of class time and field training, as well as individual capstone service projects. The first Tejon Ranch class was held in the fall of 2013, and many of the projects — which included acorn monitoring, pronghorn surveys, a weather station and a camera network to monitor wildlife — are ongoing. Training will continue yearly, and graduates will also guide wildflower and natural history tours, and, ultimately, staff the ranch’s nature center.

“We have 20 graduates who are already providing valuable citizen science work,” says Scot Pipkin, public access coordinator of the Tejon Ranch Conservancy. “This program provides an excellent foundation for our volunteers.”

### WATER QUALITY, QUANTITY AND SECURITY STRATEGIC INITIATIVE

#### Balancing grazing and watersheds

Today’s harmony between grazing and public lands in the Bay Area stems from UCCE work that began in the 1990s. Back



then, it looked like the region's grazing would soon be a thing of the past. "There were concerns that cattle were a vector for pathogens in drinking water," says Sheila Barry, UCCE livestock and natural resources advisor for the San Francisco Bay Area. "The San Francisco Public Utilities Commission (SFPUC) wanted to get rid of grazing on 40,000 acres in the East Bay."

Ranchers, some of whom had worked this land for three generations, asked Barry for help. "We had just 60 days," Barry says. Coincidentally, UCCE had just finished a statewide survey on cattle and *Cryptosporidium*, a fecal pathogen. "This was the key," she says. "We had the data to help answer the SFPUC's questions about grazing and drinking water safety."

The survey showed that *Cryptosporidium* shedding was most common in calves younger than 4 months, helping Barry and her collaborators develop a grazing plan for the SFPUC land. For example, calving has to be done by the beginning of November. "This way the young cattle are old enough not to shed by the time it rains enough for runoff to load water with pathogens," she says.

Another facet of the grazing plan is keeping cattle away from waterways. "We sat with the ranchers and went over their riparian areas and streams, and fine-tuned cattle's access to these waters," Barry says. Ongoing monitoring ensures that ranchers maintain the fences that keep herds where they should be.

Buy-in was also critical to the plan's success. "We included all stakeholders from the beginning, taking them on rangeland tours and explaining the management," Barry says. Based on the UCCE plan, in 1999 the SFPUC adopted best management practices (BMPs) for grazing watersheds. Besides preserving the livelihoods of the ranchers who came to Barry for help, the BMPs set the stage for continued grazing on public lands throughout the Bay Area.

#### ENDEMIC AND INVASIVE PESTS AND DISEASES STRATEGIC INITIATIVE

### Preparing for Africanized bees

Another UCCE project in the 1990s has had lasting benefits for the alfalfa seed industry. California is among the nation's top producers of alfalfa seed, with 38,000 acres in the Central and Imperial valleys that yield 11,000 tons of seed per year.

At the time, alfalfa seed growers were worried that the extremely defensive Africanized honey bee would soon reach the San Joaquin Valley. So they asked Shannon Mueller, UCCE farm advisor in Fresno County, to help them start using the alfalfa leafcutting bee. Unlike the European honey bee, the alfalfa leafcutting bee does not breed with Africanized bees and so cannot inherit their aggression.

While leafcutting bees were already widely used in Canada and the Pacific Northwest, no one knew how they would survive the hot temperatures and low humidity of California's interior valleys. Moreover, an alfalfa seed company had already tried to introduce them to California without success. "It was called a million dollar mistake," Mueller says.

But this time it worked. Why? "The growers and seed companies all sat down at the same table with UCCE as the conduit, sharing research-based information on what did and didn't work," Mueller says. "We learned how to manage the leafcutting bee for our conditions." This was essential because while honey bees are managed by beekeepers, leafcutting bees are managed by growers and seed companies.

Today, the combination of leafcutting bees and European honey bees is a standard in California's alfalfa seed industry. Besides giving growers an additional pollinator, the leafcutting bee increased yields by about 300 pounds an acre. This is partly because the bees pollinate alfalfa more efficiently and partly because they complement honey bees. For example, irrigation discourages honey bees but not the leafcutting bees.

"Growers have said that without the alfalfa leafcutting bee, they wouldn't be in the alfalfa seed business anymore," Mueller says. "This was a phenomenal project — it's a standout in all my years in Cooperative Extension."

—Robin Meadows



Peggy Greb, USDA ARS

Alfalfa leafcutting bee on an alfalfa flower

Chuck Deatherage of Seed Services, Inc. in Fresno checks the flight and nesting activity of alfalfa leafcutting bees, which nest in this trailer.



Shannon Mueller

# Pierce's disease costs California \$104 million per year

by Kabir P. Tumber, Julian M. Alston and  
Kate B. Fuller

*Pierce's disease of grapevines, caused by a strain of the bacteria *Xylella fastidiosa*, threatens an industry with a farm value of production exceeding \$3 billion per year. The grape industry incurs substantial costs from losses of vines to the disease and efforts to mitigate damage. Additional costs are borne by the public in providing programs that aim to contain the disease and develop longer-term solutions, and by the citrus, nursery and grape industries in complying with those programs. Aggregating the costs of vine losses, industry assessments, compliance costs, and expenditures by government entities, we estimate the cost of Pierce's disease in California is approximately \$104.4 million per year. Of that, \$48.3 million funds Pierce's disease activities undertaken by various government agencies, the nursery and citrus industries and the UC system, and \$56.1 million is the cost of lost production and vine replacement borne by grape growers.*

Pierce's disease (PD), caused by a strain of the bacteria *Xylella fastidiosa*, was first reported in the 1880s. *Xylella* blocks the xylem, or water-conducting system, of a grapevine, leading to vine death, usually between 1 and 5 years after the plant becomes diseased. This disease imposes significant annual costs on the California grape and wine industry through losses of vines and the cost of efforts to mitigate the damage. Further significant costs are borne by the broader community in providing public programs that aim to contain the problem and develop longer-term solutions, and by the citrus, nursery and grape industries in complying with those programs.

California production of grapes of all types was valued at approximately \$3.2 billion in 2010, of which wine grapes accounted for nearly \$2.1 billion, or 66%



Jack Kelly Clark

Since the late 1990s, tens of millions of dollars in public and private funding have been spent each year to prevent the spread and mitigate the effects of Pierce's disease in California.

of the total (CDEA 2011a). In our study, we focused on the wine grape industry, which accounts for the majority of grape acreage and value of grape production in California and bears the greatest share of the costs of PD (NASS 2011a, 2011b). Although PD can affect all grapevines, the Pierce's Disease Control Program (PDCP) was introduced in 2000 mainly because of concern about the costs in the wine grape industry.

Until recently, PD was regarded as just one of many chronic diseases in the wine grape industry, always present and occasionally worse than usual. This was so when the only insect vectors for the disease were native sharpshooters. Concerns grew after a devastating PD outbreak in the Temecula Valley in Southern California in the late 1990s, spread by a new nonnative vector, the glassy-winged sharpshooter (*Homalodisca vitripennis*, GWSS). In response, extensive programs were created to manage PD and GWSS in Southern California and to prevent the spread of GWSS into other areas, especially the high-production-value areas of the Napa and Sonoma valleys, but also the contiguous southern San Joaquin Valley,

where a large share of the total volume of California wine is produced, along with table and raisin grapes.

Since the inception of these programs in the late 1990s, tens of millions of dollars of public and private funds have been spent each year to prevent the spread of GWSS and PD and to mitigate the effects of PD. In our study, we quantify in detail the costs of these efforts and the costs to growers (ultimately shared with consumers) from losing vines to the disease.

## Pierce's disease and its vectors

PD has caused vine death from the very beginning of the wine industry in California. In 1857, the Los Angeles Vineyard Society settled in the Santa Ana Valley with initial funds of \$100,000. The settlement produced its first vintage in 1860, yielding about 2,000 gallons of wine. By 1883, the region was home to 50 wineries, approximately 10,000 acres of vines and annual production of about 1.2 million gallons of wine. A few years later,

Online: <http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v068n01p20&fulltext=yes>  
doi: 10.3733/ca.v068n01p20



however, most of the vines had inexplicably died. Farmers altered their farming practices, including their spraying, dusting and pruning methods, to try to combat the vine death, but were unsuccessful. The disease spread to neighboring areas and contributed to the eventual demise of commercial grape culture in Southern California (Olmstead and Rhode 2008).

In 1889, the U.S. Department of Agriculture (USDA) dispatched Newton B. Pierce to Santa Ana to determine the cause of vine death. In 1891, after extensive research, Pierce concluded that the disease was unknown and that it was probably caused by a microorganism for which a cure was not available. Pierce's conclusion closed investigations into the disease for almost 50 years (Olmstead and Rhode 2008).

The disease that killed the grapevines in Santa Ana, now referred to as Pierce's disease, and its insect vectors were not identified until recently. It is now known that the bacterium *X. fastidiosa* causes PD, and it is spread by a variety of leafhopper insects, called sharpshooters. Sharpshooters obtain nutrients by feeding on plant fluids in the water-conducting tissues of a plant (xylem). Their feeding does not usually inflict significant plant damage, although in some cases significant water loss (but not fruit damage) can occur in citrus trees. However, when a sharpshooter feeds on a PD-infected plant, the bacteria may attach to its mouthparts. Over time, the bacteria

# BACTERIUM

*discovered to be cause of*  
**PIERCE'S DISEASE OF GRAPEVINES**

## Early conclusions on Pierce's disease

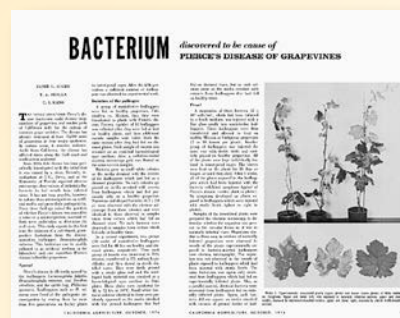
**1974** "The newly discovered Pierce's disease bacterium could destroy large numbers of grapevines and render parts of California unfit for the culture of common grape varieties.

"Since 1884, this disease has been periodically investigated with the belief that it was caused by a virus. . . . This study reports for the first time the isolation of a rod-shaped, gram-positive bacterium from the disease-spreading leafhopper *Draeculacephala minerva*.

"A group of noninfective leafhoppers were fed on healthy grapevines, *Vitis vinifera* cv. Mission, then they were transferred to plants with Pierce's disease. Excreta (spittle) of 10 leafhoppers was collected after they were fed at first on healthy plants, and then additional excreta samples were taken from the same vectors after they had fed on diseased plants. Each sample of excreta was streaked on an enriched bacteriological agar medium.

"Bacteria grew as small white colonies on the media streaked with the excreta of the leafhoppers which had fed on a diseased grapevine. No such colonies appeared on media streaked with excreta from leafhoppers which had fed previously only on a healthy grapevine.

"These experiments have demonstrated that a gram-positive bacterium is the etiological agent of Pierce's disease in grapevines, and not a virus, as previously believed. The organism has been successfully cultured on artificial media. By using the leafhopper vector injected with the cultured and purified bacteria, the disease symptoms can be consistently reproduced in healthy grapevines and the same organism reisolated from clean leafhoppers fed on these plants and on naturally infected plants from the field."



All three authors contributed to the understanding and prevention of plant diseases throughout their university careers. Jaime G. Auger studied plant pathology at UC Davis in the 1970s and went on to a professorship at the Departamento de Sanidad Vegetal, Universidad de Chile, Santiago. Thomas A. Shalla served as professor in the UC Davis Department of Plant Pathology. Besides his classroom work, he pioneered new electron microscopy techniques for the identification and study of viruses and infected plant cells, and led a task force to research and virtually eliminate pear decline, a serious disease in the state's pear industry in the 1960s. Clarence I. Kado is professor emeritus at the UC Davis Department of Plant Pathology. He was a university bacteriologist, both in the classroom and in the laboratory, and author of many scientific articles and a major college textbook on bacteriology.

**100**  
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Vectors of Pierce's disease include the blue-green sharpshooter (*Graphocephala atropunctata*), top, and the nonnative glassy-winged sharpshooter (*Homalodisca vitripennis*), bottom.

colonize the insect's foregut, and can be spread to other plants as it feeds, thus vectoring the disease (UC IPM 2008).

Several sharpshooters are native to California. Green sharpshooters and red-headed sharpshooters pose some threat to the state's vineyards, but significantly less threat than the blue-green sharpshooter (*Graphocephala atropunctata*), which has been present in the Napa Valley for over 100 years. Riparian areas provide the main breeding habitat for blue-green sharpshooters, although irrigated landscaped areas can also host breeding populations (PD/RHW 2000). They migrate out of riparian areas in the spring and into vineyards, where they can vector PD. Blue-green sharpshooters have a limited flight range; they do not fly far from where they hatch (UC IPM 2008).

GWSS was inadvertently introduced to Southern California in the early 1990s; its native habitat is in the southeastern United States and northern Mexico (Purcell and Almeida 2010). It is likely that it arrived as an egg mass in ornamental or agricultural plant foliage. GWSS can live in many habitats, including agricultural crops, urban landscapes, native woodland and riparian vegetation. It has a strong preference for citrus groves as a host; however, its host range can vary significantly and includes woody ornamentals (shrubs and trees) and annual and perennial herbaceous plants. GWSS also has the ability to fly a quarter mile or more without stopping, making it a highly mobile threat. In Southern California and the San Joaquin Valley, it is active in winter and has at least two generations per year, substantially increasing the threat of the disease spreading there (UC IPM 2008).

### Regional profiles

California's wine grape production is regionally diverse, with substantial variation in both the susceptibility of vineyards to damage from PD and the prevalence of different species of sharpshooters, and in the cultural methods used, yield per acre and value per ton of grapes. Reflecting this diversity, data on wine grape production are available for a total of 17 crush districts. For the purposes of the present analysis, we divided California into six regions that differ in terms of economic aspects of wine grape production and susceptibility

Fig. 1. California wine grape production regions.



to PD (fig. 1). Details on value of production, average price, yield and bearing acres in each region are given in table 1.

**Southern California.** Southern California is the smallest producing

TABLE 1. Details of wine grape production, by region, 2010

Region	Value of production	Weighted average price	Total crush volume	Bearing area
	\$ millions	\$/ton	1,000 tons	acres
Napa-Sonoma (Districts 3, 4)	835	2,526	331	100,424
Coastal (Districts 1, 2, 5, 6, 7, 8)	670	1,031	650	124,817
San Joaquin Valley north (Districts 11, 17)	336	477	705	84,530
San Joaquin Valley south (Districts 12, 13, 14, 15)	531	290	1,833	132,861
Southern California (District 16)	5	1,192	4	1,012
Northern California (Districts 9, 10)	39	588	66	13,274
<b>Total</b>	<b>2,416</b>	<b>673</b>	<b>3,589</b>	<b>456,918</b>





The glassy-winged sharpshooter, native to the southeastern United States and northern Mexico, was inadvertently introduced to Southern California in the early 1990s and can live in many habitats, including agricultural crops, urban landscapes, native woodland and riparian vegetation.

region: in 2010, it accounted for less than 1% of crush value and volume (\$4.74 million and 4,000 tons) (NASS 2011b), but it has been a hot spot for PD and GWSS since 1999. In that year, vineyards in the Temecula Valley, in Riverside County, began suffering great losses from PD after GWSS entered the area and began vectoring the disease. By the end of August 1999, over 300 acres of grapevines in the valley were affected (CDFA 2009a).

Wine grape production in Temecula is currently protected by the PDCP, which arranges and pays for imidacloprid, a neonicotinoid insecticide, to be applied in citrus groves adjacent to vineyards. Although these efforts to limit the size of the GWSS population in Temecula and mitigate its effects have been largely successful in many ways, PD and GWSS remain a major threat in the eyes of many vineyard owners and policymakers. GWSS exists in other parts of Southern California but has not become well established except in Temecula.

**Napa-Sonoma.** In 2010, the Napa-Sonoma region produced approximately 10% of the total crush volume, which accounted for 35% of the total value of the California wine grape crush in that year (NASS 2011c). PD, vectored by the native blue-green sharpshooter, causes significant chronic losses in this region, especially in vineyards adjacent to riparian areas, where the sharpshooter does most of its feeding.

In this region, effective pesticides are lacking because of the regional climate and dominant soil types. Some growers have undertaken extensive riparian revegetation projects to remove (often non-native) host plants and replace them with native nonhost plants, but this process is

quite costly and complicated. Extensive programs have been established to prevent the spread of GWSS into Northern California vineyards.

**Other coastal.** Coastal regions outside Napa-Sonoma constitute the second-largest wine grape region in California, producing about 18% of total crush volume and 28% of crush value in 2010. This has been the fastest-growing wine grape region in the state over the past 10 to 15 years, with acreage nearly doubling from 66,000 acres in 1997 to 125,000 acres in 2010 (NASS 1995–2012). PD is present in the coastal valleys, but prevalence is very low. Native sharpshooters such as the blue-green and willow sharpshooters are its primary vectors. Small hot spots of PD exist in parts of San Luis Obispo, Santa Barbara, Ventura and Mendocino counties, but the damage has not been extensive enough to warrant taking precautionary measures to stop its spread. Growers tend to avoid planting vineyards in the hot spots.

**San Joaquin Valley south.** In 2010, the southern portion of the San Joaquin Valley produced approximately half of California's wine crush volume, and about 22% of the wine crush value. In addition to wine grapes, the region produces nearly all of California's raisin and table grapes, which produced approximately \$1 billion in revenue in 2010 (CDFA 2011a). PD pressure here is not as severe as in either Napa-Sonoma or Temecula. Nevertheless, great measures are being undertaken to prevent PD outbreaks and the northward migration of GWSS from the Temecula Valley, where its population is abundant.

**San Joaquin Valley north.** In 2010, the northern portion of the San Joaquin

Valley produced about 20% of California's wine grape crush volume, 14% of the crush value. Here, PD pressure is relatively low, partly because of the programs and policy that have worked to prevent the northward migration of GWSS.

**Northern California.** Northern California and the Sierra Foothills account for a small share of California wine grape production — about 2% of the crush volume and about 1.6% of the crush value. The region has had minor instances of PD and no cases of GWSS. It is widely held that a GWSS population could not sustain itself over the winter here because of the cold temperatures.

## Programs

Since the PD outbreak in Temecula in 1999, several programs have been initiated to help prevent the spread of GWSS and mitigate losses from PD in California, not just in wine grape production, which is our primary emphasis, but also in table grapes and raisins.

**Research.** In 2006, the UC Pierce's Disease Research Grants Program was established with funding from the USDA Cooperative State Research, Education, and Extension Service (CSREES) to allocate funds to research aimed at preventing the spread of PD and GWSS. Each year the federal government has



Pierce's disease is caused by a strain of the bacteria *Xylella fastidiosa*, which blocks the water-conducting system of a grapevine, leading to vine death 1 to 5 years after the plant becomes diseased.

allocated \$1 to \$2 million to the program for research. Total spending under this program in fiscal year (FY) 2009–2010 was \$1.86 million, but since 2010–2011 funding has ceased.

**Pierce’s Disease Control Program.** The largest and most influential PD-related program in California is the Pierce’s Disease Control Program (PDCP). It is a partnership that includes the California Department of Food and Agriculture (CDFA), county agricultural commissioners, the USDA, UC and California State University, other state and local agencies, and industry and agricultural organizations throughout California. The program aims to slow or stop the spread of GWSS while other short- and long-term solutions to PD are developed. In FY 2009–2010, the program spent approximately \$18.6 million on efforts to prevent the spread of GWSS from infested to noninfested areas, surveying and detection, response to outbreaks or GWSS infestations, and outreach.

**Local government and industry efforts.** Napa County funds activities for prevention of PD, as well as other diseases and pests, in conjunction with the Napa County Winegrape Pest and Disease Control District. Wine grape growers in Napa County are required to

pay an assessment (\$8.22 per acre in FY 2010–2011) (Napa County Agricultural Commissioner’s Office 2010), which Napa County is required by law to match. The funds are applied to inspection, detection, and prevention of and education about PD and GWSS, as well as detection and control of the vine mealybug (Napa 2009). In FY 2009–2010, Napa County collected approximately \$193,000 using this assessment.

In addition, in October 2001, the PD/GWSS Board was established to fast-track research efforts. The Board introduced the Statewide Winegrape Assessment (SWA), which has ranged, based on recommendations from the PDCP, from \$0.75 to \$3.00 per \$1,000 of harvested wine grape value, to support research (PD/GWSS Board 2009; Western Farm Press 2013).

**Regulatory programs.** The GWSS Nursery Shipping Protocol designates approved practices for shipments of nursery stock in California. In many cases, nurseries in infested counties must subject the plants they ship to extensive inspection when shipping to noninfested areas; every leaf of the plant must be examined (CDFA 2009b). Exceptions to some of these inspections occur if the nursery is designated “free from” GWSS, where “free from” means a nursery does not find egg

masses, live nymphs or more than three adult GWSS in the same one-half acre in a 2-week period (CDFA 2009c). After implementation of the protocol, shipments in which GWSS was detected dropped significantly, from 149 in 2001 (57,600 total shipments) to six in 2010 (50,600 total shipments) (CDFA 2011b).

### Program costs

From 1999 to 2010, industry and federal, state and local governments together spent nearly \$544 million dollars on PD and GWSS programs (fig. 2). In FY 2009–2010, the government cost was just over \$34 million, of which \$30.1 million was federal, \$3.7 million was state, \$193,000 was local government expenditures and \$161,000 was derived from the SWA (Tom Esser, special assistant to the PDCP, personal communication) (fig. 3). Figure 4 summarizes industry-funded expenditure and its allocation. Costs are also incurred by the industry to comply with the PDCP and as a result of the losses of vines to PD (tables 2 and 3).

**Federal government funding.** Between 1999 and 2010, the federal government contributed approximately \$303 million, or 74%, of the total funding for PD-related programs. In FY 2009–2010, the federal government spent approximately \$30

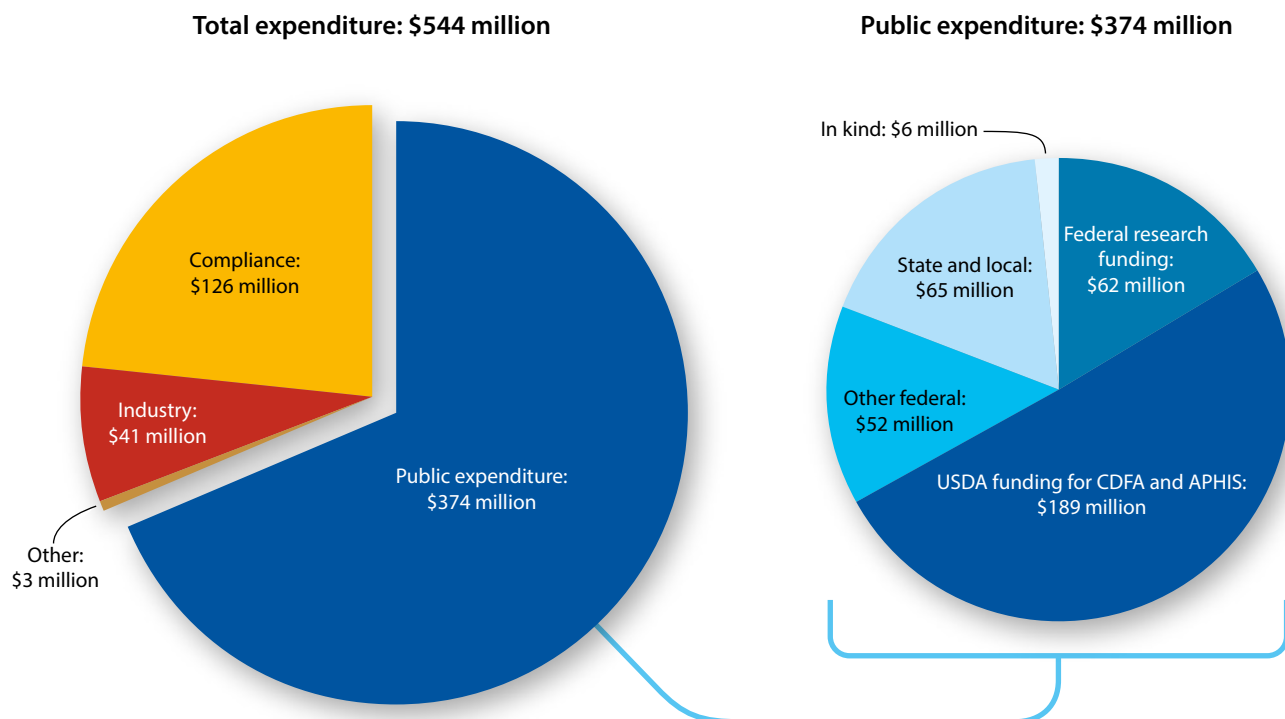


Fig. 2. Pierce’s disease program spending and cost of compliance, 1999–2010.



million on those programs: the Animal Plant and Health Inspection Service (APHIS) spent approximately \$23 million, and the Agricultural Research Service (ARS) and the National Institute of Food and Agriculture (NIFA) spent approximately \$7.1 million (fig. 3). The UC PD Research Grants Program received \$1.86 million of the ARS and NIFA allocation, and the balance of \$5.28 million funded USDA ARS programs and overhead expenses (Kassim Al-Khatib, UC PD Research Grants Program manager, personal communication).

**State and local government funding.** Between 1999 (i.e., the Temecula outbreak) and 2010, state and local governments contributed funds of nearly \$65 million, or 16%, of the total funding for PD-related programs (fig. 2). In FY 2009-2010, the CDEA contributed approximately \$3.7 million to the PDCP, which had total funding of nearly \$19.18 million, of which it spent \$6.2 million on expenses and \$12.1 million on county payments (fig. 3). The state and local government funding, in addition to the SWA, support the program's four main elements: containment,

survey and detection, rapid response, and outreach. The state of California also contributes in-kind services (e.g., scientific consultation, promulgation of regulations, environmental compliance, pesticide registrations, diagnostics, legal review, mapping and so on) worth \$250,000 annually to the program operations and \$24,000 to research.

**Industry funding.** The California grape industry contributed approximately \$41 million, or 10%, of direct funding for PD activities between 1999 and 2010 (fig. 2), mostly through the PD/GWSS

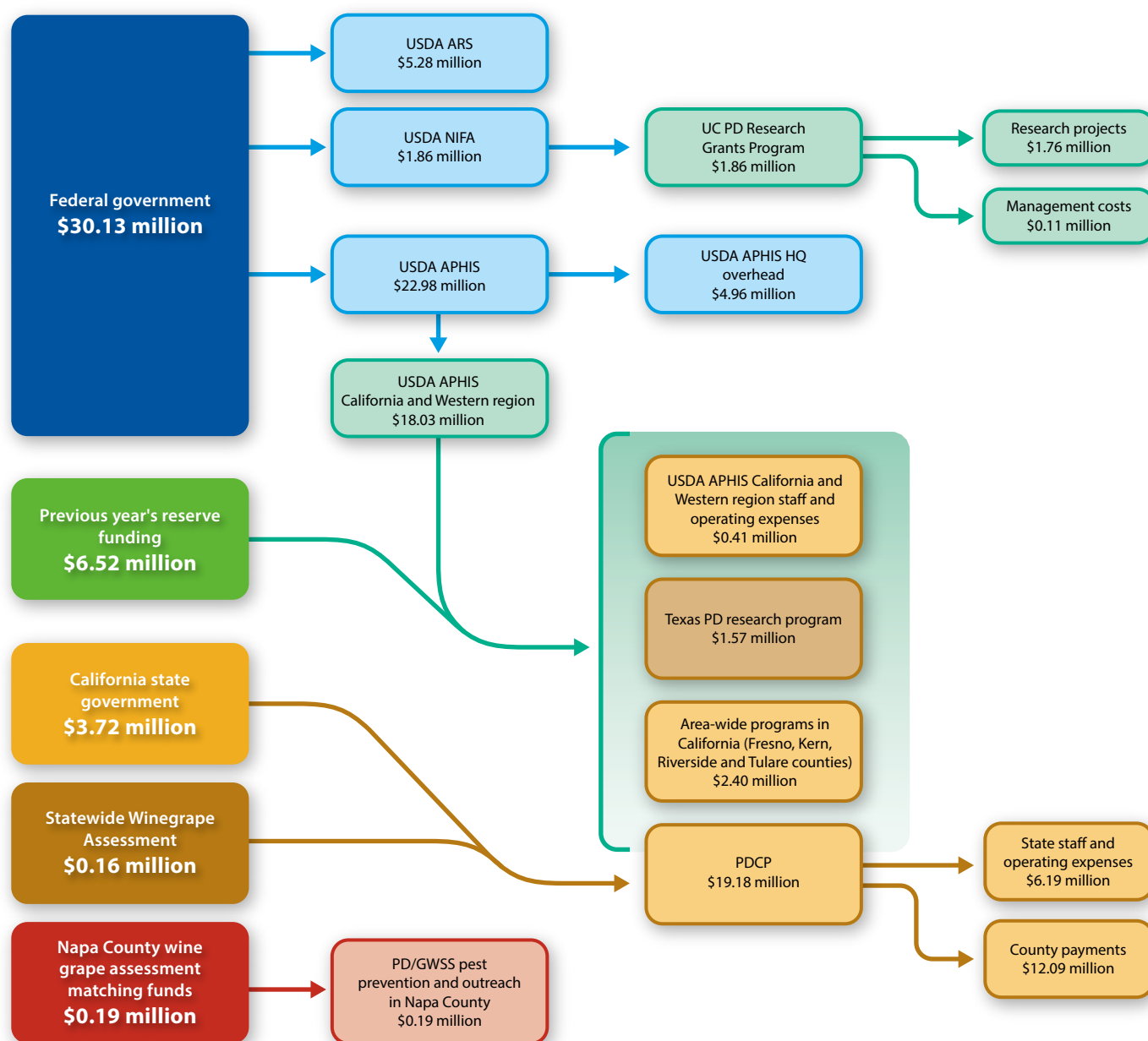


Fig. 3. State and federal funding for PD-related programs and expenditures, 2009–2010. Unused federal funds are carried over to following years as reserve funding, but state funding cannot carry over. Source: Developed by the authors using data from the PDCP, PD/GWSS Board and UC PD Research Grants Program.

Board's statewide assessments of growers. Between 2001 and 2010, the PD/GWSS Board collected approximately \$37.3 million, of which it spent approximately \$21 million on 106 research projects and four field trials, as well as another \$2 million on review and guidance of research efforts (Esser, personal communication). The annual amounts have varied. In FY 2009–2010, the industry contributed approximately \$3.1 million and some \$8 million was carried forward from the previous year, sourced and allocated as shown in figure 4. In FY 2009–2010, the SWA raised over \$2.8 million for research and related activities. Napa County's assessment, which is in addition to the SWA, contributed \$193,378 in FY 2009–2010 to the prevention of PD (fig. 4).

Similarly, table grape growers in California are charged an assessment. The Consolidated Central Valley Table

Grape Pest and Disease Control District manages the funds acquired by the assessment. In FY 2009–2010, the assessment collected approximately \$735,000, of which about 15% (or approximately \$119,000) was contributed to GWSS- or PD-related projects (Judy Zaninovich, Consolidated Central Valley Table Grape Pest and Disease Control District manager, personal communication), allocated as shown in figure 4.

#### Nursery compliance costs.

Approximately 70% of California's 12,000 licensed nurseries are located in GWSS-infested areas, and those that choose to ship from infested to noninfested areas are required to take certain precautions to avoid the spread of GWSS. Complying with CDFA-approved shipping protocols can be very expensive for nursery operators. Many nurseries have adapted their businesses to save on the costs of compliance, opening facilities in noninfested

areas or minimizing, if not eliminating, shipping to noninfested areas.

Our compliance cost estimates reflect explicit costs borne by the industry for nurseries that must comply with the GWSS Nursery Shipping Protocol measures such as inspections, pesticide sprays and quarantines. Our estimates do not include forgone business, nor expenses incurred in changing business models to comply with the approved treatment protocol, nor the costs of changing product mix, additional management costs, and lost orders because of problems with scheduling inspections. We extrapolated from data on costs provided to us by a small number of nurseries in infested areas that ship to noninfested areas, as well as informal advice on the likely range of costs for other nurseries, to estimate the compliance cost for the industry, which is diverse and fragmented; our estimate for 2010 was approximately \$6.8 million (table 2).

**Citrus compliance costs.** As a winter breeding ground for GWSS, citrus groves play an important role in determining GWSS populations. The CDFA estimates that the California citrus industry spends approximately \$3.5 million annually on programs and activities to comply with regulations to mitigate the spread of GWSS (table 2). The citrus industry has improved its effectiveness in containing the spread of GWSS through programs funded and established by the CDFA. As a result of the programs, the acreage of citrus treated for GWSS has declined substantially. In 2003, Kern County treated just over 20,000 acres and Tulare County treated nearly 40,000 acres. In 2009, Kern County treated nearly 5,000 acres and Tulare County treated about 9,500 acres.

#### Cost of vines lost to PD

California grape growers and consumers bear the greater part of the total cost of PD — more than the combined costs of nursery and citrus growers, and local, state and federal governments. Table 3 shows the estimated annual average value of vines lost to PD by region and grape type; across all regions and grape types using our most likely estimate of PD pressure, the average annual value of vines lost to PD is \$56.1 million. This value is a lower-bound estimate of total cost because it does not include costs of preventive measures taken by growers against

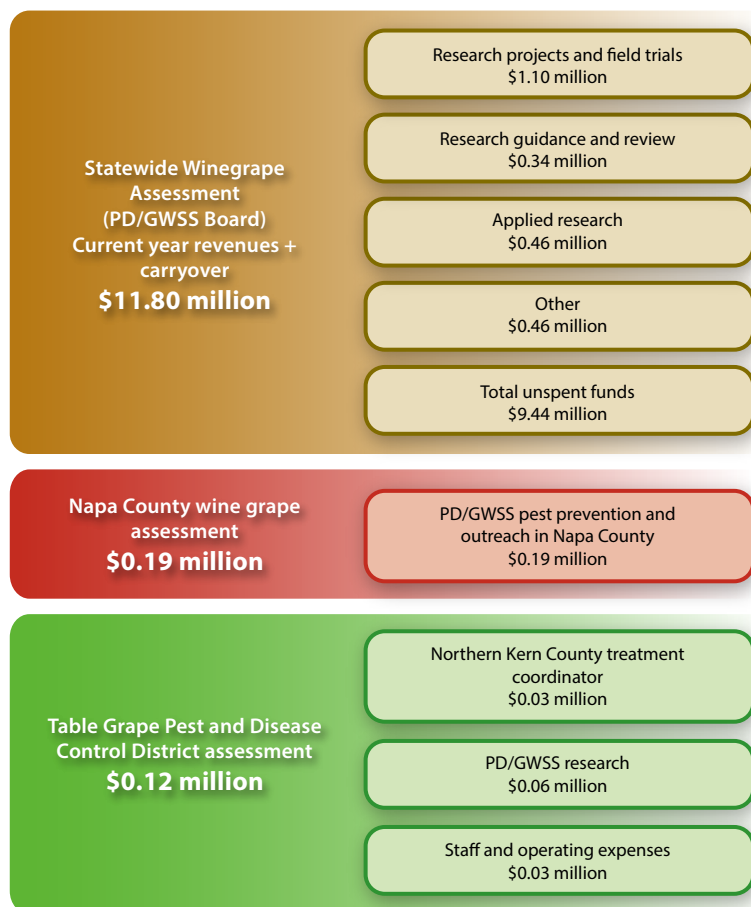


Fig. 4. Industry funding for PD-related programs and expenditures, 2009–2010. Unused funds can be carried over to following years, so funding in a particular year may not equal expenditure. Source: Developed by the authors using data from the PDCP, PD/GWSS Board and Table Grape Pest and Disease Control District.



TABLE 2. Funding for Pierce's disease activities, by California state fiscal year, 1999–2000 to 2009–2010

	1999– 2000	2000– 2001	2001– 2002	2002– 2003	2003– 2004	2004– 2005	2005– 2006	2006– 2007	2007– 2008	2008– 2009	2009– 2010	Total
..... \$1,000s .....												
<b>Federal government funding</b>												
USDA APHIS funds for Temecula	360	—	—	—	—	—	—	—	—	—	—	360
USDA allocation for APHIS and CDFA	—	—	8,500	17,500	22,119	23,003	24,079	24,079	23,013	23,175	22,983	188,451
CCC emergency funds*	22,289	—	8,714	8,770	5,182	—	—	—	—	—	—	44,955
USDA ARS and CSREES funds for research	100	2,700	5,473	6,389	7,180	7,218	7,328	5,285	6,805	6,712	7,146	62,337
Grapevine Loss Assistance Program	—	7,140	—	—	—	—	—	—	—	—	—	7,140
<i>Total</i>	<i>22,749</i>	<i>9,840</i>	<i>22,687</i>	<i>32,659</i>	<i>34,481</i>	<i>30,221</i>	<i>31,407</i>	<i>29,364</i>	<i>29,818</i>	<i>29,887</i>	<i>30,129</i>	<i>303,243</i>
<b>State and local government funding</b>												
AB 1232 funds for research	750	750	750	—	—	—	—	—	—	—	—	2,250
SB 671 allocation	6,900	—	—	—	—	—	—	—	—	—	—	6,900
State Budget Act	—	6,900	8,288	6,401	6,408	4,408	4,341	4,500	4,549	4,089	3,721	53,605
UCR Greenhouse	—	—	375	—	—	—	—	—	—	—	—	375
City of Temecula	125	—	—	—	—	—	—	—	—	—	—	125
Riverside County	125	—	—	—	—	—	—	—	—	—	—	125
Napa County†	—	—	—	180	165	150	78	180	110	190	193	1,246
<i>Total</i>	<i>7,900</i>	<i>7,650</i>	<i>9,413</i>	<i>6,581</i>	<i>6,573</i>	<i>4,558</i>	<i>4,419</i>	<i>4,680</i>	<i>4,659</i>	<i>4,279</i>	<i>3,915</i>	<i>64,626</i>
<b>Industry</b>												
AVF funds to match AB 1232‡	250	250	250	—	—	—	—	—	—	—	—	750
Statewide Winegrape Assessment§	—	—	6,163	3,927	3,777	4,109	5,593	4,945	3,539	2,411	2,848	37,311
Napa County wine grape assessment†	—	—	—	180	165	150	78	180	110	190	193	1,246
Table Grape Pest Control District(s)	—	—	—	—	—	—	399	440	448	480	119	1,886
Other	—	—	—	—	9	11	11	11	—	—	—	42
<i>Total</i>	<i>250</i>	<i>250</i>	<i>6,413</i>	<i>4,107</i>	<i>3,950</i>	<i>4,270</i>	<i>6,081</i>	<i>5,576</i>	<i>4,097</i>	<i>3,082</i>	<i>3,160</i>	<i>41,235</i>
<i>Direct funding total</i>	<i>30,899</i>	<i>17,740</i>	<i>38,513</i>	<i>43,346</i>	<i>45,004</i>	<i>39,050</i>	<i>41,907</i>	<i>39,619</i>	<i>38,574</i>	<i>37,248</i>	<i>37,204</i>	<i>409,104</i>
<b>In-kind services</b>												
State program operations	250	250	250	250	250	250	250	250	250	250	250	2,750
State research	24	24	24	24	24	24	24	24	24	24	24	264
<i>Total</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>274</i>	<i>3,014</i>
<b>Other contributions</b>												
Industry and UC participation on state task forces, boards, etc.	150	210	210	210	210	210	210	210	210	210	210	2,250
Industry and UC participation on local task forces	50	68	68	68	34	34	34	34	34	34	34	489
UC in-kind	250	250	250	250	250	250	250	250	250	250	250	2,750
<i>Total</i>	<i>450</i>	<i>528</i>	<i>528</i>	<i>528</i>	<i>494</i>	<i>494</i>	<i>494</i>	<i>494</i>	<i>494</i>	<i>494</i>	<i>494</i>	<i>5,489</i>
<i>In-kind funding and other</i>	<i>724</i>	<i>802</i>	<i>802</i>	<i>802</i>	<i>768</i>	<i>768</i>	<i>768</i>	<i>768</i>	<i>768</i>	<i>768</i>	<i>768</i>	<i>8,503</i>
<b>Compliance costs</b>												
Nursery industry	4,000	7,800	8,900	8,800	10,400	9,800	9,300	9,900	8,400	7,200	6,800	91,300
Citrus industry	—	1,175	2,350	3,525	525	3,525	3,525	3,525	3,525	3,525	3,525	31,725
Grape industry	—	605	605	605	605	605	300	100	—	—	—	3,425
<i>Total</i>	<i>4,000</i>	<i>9,580</i>	<i>11,855</i>	<i>12,930</i>	<i>14,530</i>	<i>13,930</i>	<i>13,125</i>	<i>13,525</i>	<i>11,925</i>	<i>10,725</i>	<i>10,325</i>	<i>126,450</i>
<b>Grand total</b>	<b>35,623</b>	<b>28,122</b>	<b>51,169</b>	<b>57,078</b>	<b>60,302</b>	<b>53,747</b>	<b>55,800</b>	<b>53,912</b>	<b>51,266</b>	<b>48,740</b>	<b>48,297</b>	<b>544,057</b>

Sources: Tom Esser, special assistant to the PDCP, personal communication, and authors' calculations.

\* CCC = Commodity Credit Corporation.

† For PD/GWSS activities.

‡ AVF = American Vineyard Foundation.

§ Includes interest.

¶ Total assessment, not 100% contributed to PD/GWSS activities.

The federal fiscal year runs from October 1 to September 30. The state fiscal year runs from July 1 to June 30.

Figures include funding appropriated, collected, or allocated in that fiscal year, regardless of the fiscal year in which the funds were actually spent.

TABLE 3. Expected cost of vine losses, by grape type and region, 2010

Type and region	Bearing area	Value of vines lost to PD		
		Low PD pressure	High PD pressure	Most likely PD pressure
	<i>1,000 acres</i>	<i>..... \$ millions .....</i>		
Wine grapes				
Napa-Sonoma (Districts 3, 4)	100.4	13.0	93.1	33.5
Coastal (Districts 1, 2, 5, 6, 7, 8)	124.8	0.0	29.2	6.5
San Joaquin Valley north (Districts 11, 17)	84.5	0.0	4.3	2.1
San Joaquin Valley south (Districts 12, 13, 14, 15)	132.9	0.0	13.7	4.7
Southern California (District 16)	1.0	0.2	1.2	0.6
Northern California (Districts 9, 10)	13.3	0.0	1.5	0.2
<i>Total wine grapes</i>	<i>456.9</i>	<i>13.2</i>	<i>143.0</i>	<i>47.7</i>
Raisin grapes				
San Joaquin Valley south (Districts 12, 13, 14, 15)	200.2	0.0	7.0	3.2
Southern California (District 16)	1.1	0.1	0.3	0.1
<i>Total raisin grapes</i>	<i>201.4</i>	<i>0.1</i>	<i>7.3</i>	<i>3.3</i>
Table grapes				
San Joaquin Valley (Districts 12, 13, 14, 15)	71.5	0.0	10.0	2.9
Southern California (District 16)	7.0	0.9	4.6	2.3
<i>Total table grapes</i>	<i>78.5</i>	<i>0.9</i>	<i>14.6</i>	<i>5.2</i>
Total grapes	736.8	14.2	165.0	56.1

Sources: Acreage is from NASS 2011a; other data from UCCE 2000–2011 and authors' calculations.

sharpshooters, including revegetation of riparian areas and pesticide use, or losses from land left idle. Examples of the calculations used to determine the table 3 values are given in table 4. The cost of these losses is the forgone net revenue from vines that die, plus the costs of roguing and replanting diseased vines. After discounting to the present value, the cost of replacing a diseased vine in Napa County was estimated to be \$43.19 (table 4).

Table 3 shows the bearing acreage and corresponding costs to growers of wine, raisin and table grapes, by region, over a range of PD pressure, for which the most likely estimates imply an annual loss of \$56.1 million by California grape growers. We drew on expert opinion to define the range and the most likely rates of disease pressure since hard data are not available; the value of lost vines ranges from \$14 million (low PD pressure) to \$165 million (high PD pressure) per year. The largest share of losses comes from wine grapes, followed by table and then raisin grapes. Of the wine grape regions, Napa-Sonoma (Districts 3 and 4) is the hardest hit, losing an estimated \$34 million per year, making up more than half of the total losses to growers. District 4 (Napa County) has the highest annual losses, at over \$23 million, because it has a relatively high rate of PD (0.75%) and the highest average price

TABLE 4. District 4 sample calculation of costs of vine loss, 2010

Years after vine death	New vine planted in year 1				Mature vine		Net loss		
	Establishment cost*	Yield	Operating cost†	Net revenue§	Forgone net revenue#		Current cost††	Discounted present value‡‡	
	<i>\$/vine</i>	<i>tons/acre</i>	<i>\$/acre</i>	<i>\$/acre</i>	<i>\$/acre</i>	<i>\$/vine**</i>	<i>\$/vine</i>	<i>\$/vine</i>	
0	—	—	—	—	—	10,600	6.82	6.82	6.82
1	13.81	0.0	0	0	0	10,600	6.82	20.62	19.64
2	1.50	0.0	0	0	0	10,600	6.82	8.32	7.54
3	0.00	1.0	3,384	–148	–0.10	10,600	6.82	6.91	5.97
4	0.00	3.0†	5,199	4,511	2.90	10,600	6.82	3.92	3.22
5	0.00	5.0	5,582	10,600	6.82	10,600	6.82	0.00	0.00
<b>Total loss</b>								<b>43.19</b>	

Authors' calculations based on (a) \$3,236/ton, the volume-weighted average revenue per ton across all varieties in 2010 for District 4 from NASS 2011b, and (b) yields, all costs, and 1,555 vines per acre from UCCE 2012 and (c) a 5% discount rate.

\* Costs incurred in years 1 and 2, before the vine becomes commercially bearing; these include costs of stump removal, planting the new vine, pruning and training. Year 1 has the highest per-vine establishment costs because that is when the vine is purchased and planted.

† Estimated as the average yield between year 3 and year 5 because year-4 yield was not explicitly stated in the cost and return studies.

‡ Costs incurred in year 3 and later, once the vine becomes commercially bearing; these include costs of pruning, application of fertilizer and pesticides, and harvesting.

§ Average gross revenue per ton of grapes crushed multiplied by yield in tons per acre, minus operating costs.

¶ Previous column divided by vines per acre.

# Maximum yield per acre multiplied by the average gross revenue per ton, minus operating costs.

\*\* Previous column divided by vines per acre.

†† Forgone net revenue per mature vine plus establishment costs, minus net revenue from current production.

‡‡ Value of the annual net loss per vine over time discounted to the present, discounted using a 5% real discount rate.



for grapes in the state, such that the value of the forgone net revenue is higher than in other areas. The same is true, but to a lesser extent, for District 3 (Sonoma and Marin counties).

### Total and potential costs of PD

Aggregating the costs of vine losses and industry assessments paid by wine and table grape growers, compliance costs for nursery owners and citrus growers, and expenditures by government entities, the estimated cost of PD in California is approximately \$104.4 million per year. The total cost is comprised of \$48.3 million in funded activities undertaken by

undertaken by growers, and thus can be considered a lower bound for total costs. A more complete examination of the costs of the disease to growers would include costs of preventive measures, but techniques vary greatly and the costs are not easily quantifiable. In the North Coast, prevention techniques include various forms of riparian revegetation, green fencing and pesticide application, while in Southern California insecticide application is by far the most common and effective tool in controlling sharpshooters.

The estimates of costs to growers reported here are conditioned by the presence of the prevention programs that

limit the spread of GWSS. Future funding for PD-related programs is in doubt, given general budget issues combined with the arrival of

new pests and diseases, which compete for funds and attention, and relatively low PD incidence in recent years. Indeed, the UC PD Research Grants Program has already ceased. Such decisions might come at a high cost.

In a related study, using a simulation model of the market for California wine grapes, we estimated that if GWSS

were to become distributed throughout California, average annual costs of PD borne by growers, and ultimately consumers, of wine grapes would increase by \$185 million under the most likely scenarios (Alston et al. 2013). Compared with the potential costs of PD, the current costs of Pierce's disease programs are relatively modest.

## California grape growers bear \$56.1 million in production losses each year, and \$48.3 million is spent on prevention by nurseries, government agencies and the UC system.

various government agencies, the nursery and citrus industries and the UC system, and \$56.1 million in costs of lost production and vine replacement borne by wine, table and raisin grape growers.

These figures do not include any of the substantial costs of preventive measures against the spread of GWSS and blue-green sharpshooters within vineyards

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# Seniors, and their food handlers and caregivers, need food safety and nutrition education

by Mary L. Blackburn, Christine M. Bruhn, Lisa Soederberg Miller, Chutima Ganthavorn and Beth Ober

*Seniors are at greater risk than other adults for foodborne illness, poor nutrition and high rates of nutrition- and lifestyle-related chronic diseases. They also represent a major underserved segment of the UC Cooperative Extension client population. The Make Food Safe for Seniors (MFSFS) initiative assessed food safety and nutrition education needs of fixed-income seniors and food handlers and caregivers serving seniors in 10 California counties. Baseline survey results found unsafe practices by over 50% of the participants in six areas — and by over 65% of participants in three of those areas. After one food safety training, a post-test showed an average knowledge gain of 18.1%; seniors had gained the least knowledge, food handlers had gained some knowledge, and caregivers had gained the most. The unsafe food handling practices of a majority of the study group, as well as poor food behaviors, suggested areas in which education could reinforce or improve food safety, healthy eating and disease prevention practices of seniors, caregivers and food handlers serving seniors.*

The coming of age of baby boomers accelerated the rate at which California's population is turning gray. In "The Graying of California," a special issue of this journal, UC Division of Agriculture and Natural Resources (UC ANR 2010) acknowledged this as an emerging concern. Public health professionals for many years have been concerned that the workforce is not adequately prepared for the needs of America's aging population (Krisberg 2005). In our research we were concerned about the rapidly increasing numbers of older Californians at greater risk for foodborne illness (food poisoning) as well as



Nelly Camacho

In a study of the food safety and nutrition practices of senior citizens and their food handlers and caregivers, UC Cooperative Extension researchers identified a need for food safety and nutrition curricula aimed at seniors and those who prepare their food. Above, participants at a food safety training in Alameda County learn how to calibrate a food thermometer.

their need for nutrition education to promote healthy aging (Blackburn 2010).

## Risk of foodborne illness

Adults over the age of 60 are more likely than younger adults to experience complications, hospitalization and death because of foodborne infections (Cates et al. 2009). Seniors with diminished capacity or physical impairment — who are taking multiple medicines or have weakened immune systems — are less able to fight foodborne pathogens, such as *Salmonella*, *Escherichia coli* O157:H7 and *Listeria*, and other bacterial or viral infections (Kendall et al. 2006).

About 80% of seniors in the United States have at least one chronic health condition, and 50% have at least two; some chronic conditions render them more susceptible to foodborne illness (CDC 2011a). About 3.6 million Californians are over age 65. At least 55% of these seniors suffer from hypertension, 50% from arthritis, 24.0% from heart disease, 17.3% are diagnosed with cancer and 14.8% have diabetes. These top five chronic disease conditions vary significantly in California by ethnic group (Wallace et al. 2003) (fig. 1).

Of major concern are those seniors who are suffering from deficits in memory functioning. Lapses in episodic memory (the recollection of personally experienced events) are an important contributing factor to unsafe food handling, missed or mistakenly repeated doses of medications and other high-risk behaviors (Ober 2010). This memory impairment is the hallmark of Alzheimer's disease, which occurs in 14.7% of 85-year-olds and 4.2% of 75-year-olds (Brookmeyer et al. 2007).

Safe food handling knowledge and skills are critical for seniors so they can recognize unsafe practices that may be used by untrained food handlers in community-based organizations or by untrained agency or kinship caregivers who lack knowledge of safe food handling. Many who provide food to seniors in need of assistance may not be aware that elderly populations are more vulnerable to foodborne illness. The population of seniors receiving care is significant:

Online: <http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v068n01p30&fulltext=yes>  
doi: 10.3733/ca.v068n01p30



California's In-home Supportive Services's case load in June 2012 was 432,650 people (CAPA IHSS 2012).

Low availability of food, insufficient resources and hunger may also contribute to the risks of foodborne illness among seniors. Hoarding food is a natural response in times of limited food supply, and unsafe food items may not be discarded. Concerns about finances among limited- and fixed-income elders in the current economic environment may be escalating: poverty estimates indicate that 810,000 of 4.3 million older Californians live in poverty (Bohn et al. 2013), and many fixed-income seniors live on an income that is 50% or less of the benchmark income for poverty in the United States.

### Causes of foodborne illness

Primary factors contributing to foodborne illness are improper temperature, inadequate cooking, contaminated utensils or equipment, eating food from unsafe sources and poor personal hygiene. Research shows that elders who take food home from group sites or have home-delivered meals may fail to properly store or reheat the food. A study of the average wait time between when prepared meals are home delivered and when they are consumed found 63% of seniors ate their meals when delivered, 29% stored them in the refrigerator or freezer and 8% left

## Foodborne illness in California

In 2011, the Centers for Disease Control (CDC) estimated that annually one in six Americans, or 48 million people, experience a foodborne illness; 128,000 are hospitalized, and 3,000 die (CDC 2011b). An earlier report combining data from multiple surveillance systems and sources estimated foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations and 5,000 deaths in the United States annually (Mead et al. 1999). A recent study using the CDC model to determine cost, and adding consideration for pain suffering and functional disability, estimates an annual cost for foodborne illness of \$77.7 billion (Scharff 2012). Increased rates of food-borne illness are associated with eating more food away from home, emerging food-borne pathogens, and a growing aging population more susceptible to foodborne illness.

The Centers for Disease Control Food Net Report (CDC 2011c) found a significantly higher incidence of at least five pathogens (*Campylobacter*, *Listeria*, *Salmonella*, *Shigella* and *Vibrio*) in California compared to a 10-state average. Cases of *Campylobacter* in California were 32.50 per 100,000 compared to the 10-state average of 13.52 cases (CDC 2011c). A 10-year review of California outbreaks from 1998 to 2007 found restaurants and other food establishments to be the most common locations for outbreaks (44%), followed by private homes (21%), multiple locations or unknown (8%) and the workplace (7%) (CSPI 2011). California Department of Health Services reported about 26% of foodborne illness is associated with food prepared in community locations such as potlucks or church dinners, 46% with restaurants, 19% with in-home preparation and 6% in schools (Wang 2000).

them out. About 35% reported leftovers, but only 12% ate the leftovers within 2 hours as recommended (Almanza et al. 2007).

Another assessment of home-delivered meals ( $n = 179$ ) found 58% of mostly older (age 80 and above) seniors stored all or some of the food. Of the older seniors who saved their food, 38% stored it in the

refrigerator, but 30% stored it on the counter (Fey-Yensan et al. 2001). A study of 120 senior meal recipients, mostly females over age 70, found about 64% knew the importance of hand-washing but were not aware of when and how to wash hands (Lee et al. 2009). Lee and colleagues also found that home-delivered meal recipients ( $n = 97$ ) had an average score of 63.8% in food handling, but 49% for cleaning, sanitizing and washing dishcloths.

A national representative Web-based survey ( $n = 2,060$ ) examined refrigerator temperatures, use of thermometers and frequency of cleaning home refrigerators. About one half of all participants in the study had cleaned their refrigerator in the last month, but only 11% had a thermometer in their refrigerator (Kosa et al. 2007). More of the older adults (77.5%) were likely to have their refrigerator at the right temperature than the younger population (70.4%). However, older adults who were unmarried or lived alone were less likely to have a thermometer or have their refrigerator at the recommended temperature (40°F or below). More recent research shows an increasing trend in consumer food thermometer ownership from 49% in 1998 to 70% in 2010. The study found the elderly, 65 to 101 years old, were less likely to use a food thermometer for roasts and chicken parts than adults 18 to 29 years old (Lando and Chen 2012).

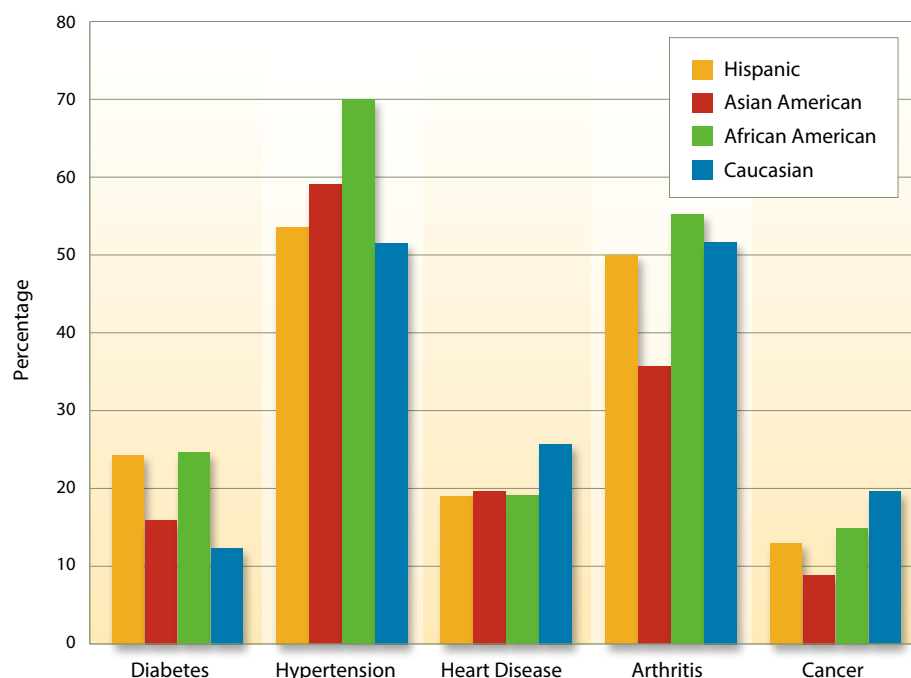
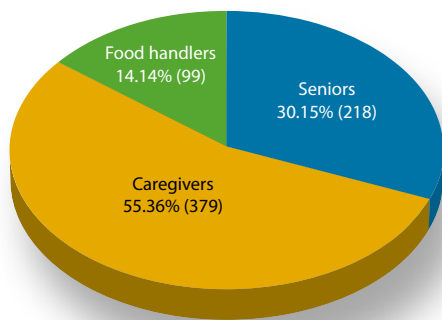
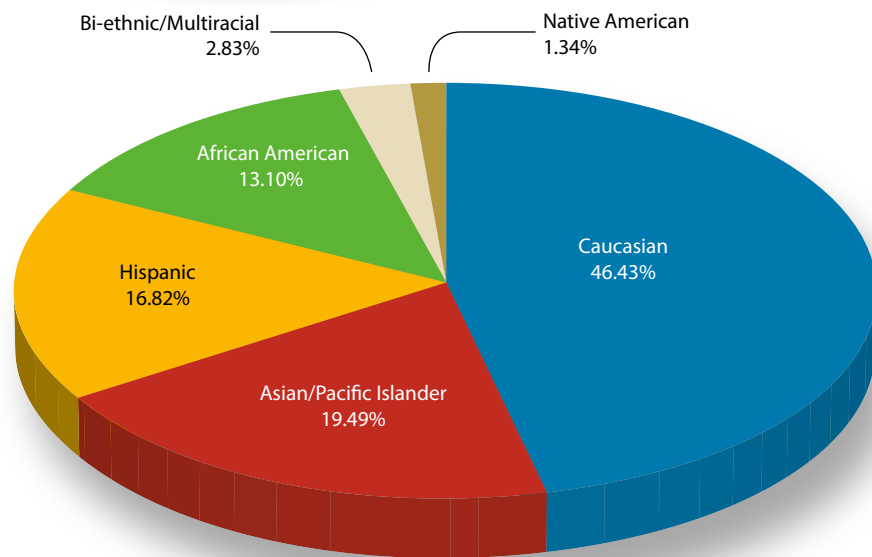


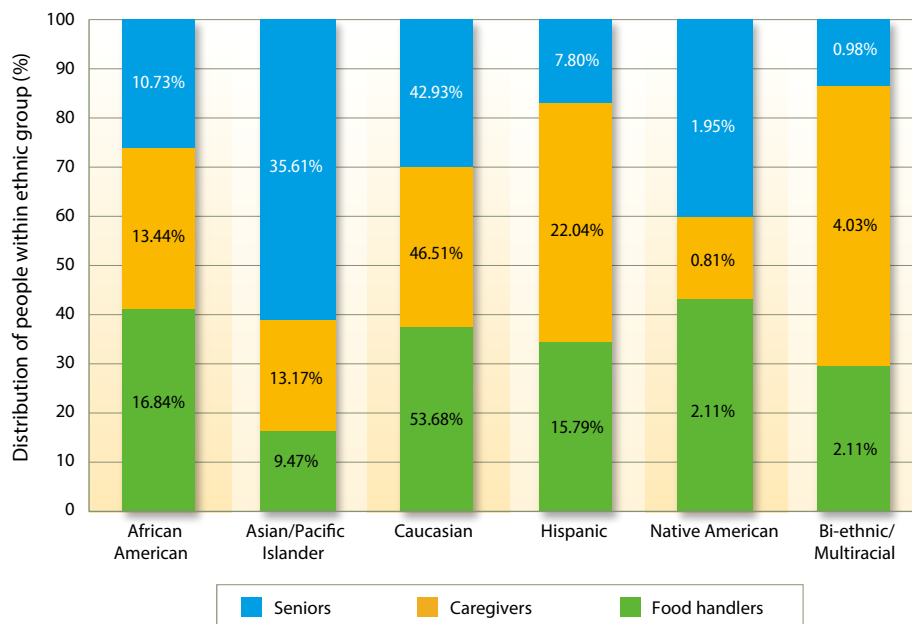
Fig. 1. Top five chronic diseases in California by ethnic group. Source: Wallace et al. 2003.



**Fig. 2.** Study group was composed of 696 participants, including seniors who volunteered from senior centers and senior programs, caregivers from in-home supportive services and family or relative caregivers, and food handlers from church communities and food pantries.



**Fig. 3.** Study participants by ethnic distribution. Total number of participants who provided ethnic information was 672.



**Fig. 4.** Ethnicity of the seniors, caregivers and food handlers (read each color across the figure); and within each ethnic group, the percentage who were seniors, caregivers and food handlers (read the size of each color unit against the vertical axis).

## Make Food Safe for Seniors (MFSFS)

The Make Food Safe for Seniors (MFSFS) initiative is a joint research venture, funded by a CORE issues grant, between two UC ANR workgroups — Aging Californians in Rural and Urban Settings, and Food Safety. The research team was comprised of two Agriculture Extension Station scientists focusing on aging; a Cooperative Extension food safety specialist; nine Nutrition, Family and Consumer Sciences (NFCS) advisors; and county directors and community collaborators in 10 counties.

The objectives of the MFSFS initiative were to a) determine the baseline nutrition education and food safety needs of limited- or fixed-income seniors, food handlers in senior services and in-home caregivers, b) increase the food safety knowledge and skills of the study group, c) increase public awareness of the higher risk of foodborne illness among elders, d) use the findings to create senior-friendly curricula and materials to help reduce the risk of foodborne illness and e) promote healthy food practices for vulnerable elders in local California counties.

**Local needs assessments.** The MFSFS team reviewed existing research and assessments of nutrition and food safety needs in local counties. Research by Barrett et al. (2005) with in-home caregiver trainees ( $n = 482$ ) in Sacramento and Yolo Counties documented a dire need for standardized nutrition education and safe food handling curricula for caregivers working with frail elders aging in place. The 2009 California Health Interview Survey health risk data for baby boomers (both informal caregivers [ $n = 5,688$ ] and noncaregivers [ $n = 12,941$ ]) show that those who are also caregivers have greater odds of overall negative health behaviors associated with disability and chronic illnesses (Hoffman et al. 2012).

Blackburn (2010) assessed the nutrition and wellness needs of limited-income seniors at 20 sites ( $n = 377$ ) in Alameda County. About 40% of the seniors reported multiple chronic diseases, and approximately 88% expressed a need for more healthy nutrition, lifestyle and food safety information, for example on cooking, preventing spoilage, and storing food over extended periods.

A 2005 Aging Californians workgroup survey of 27 NFCS advisors and county directors found few counties offered



senior programs, but 86% said aging programs were needed in their counties (2005 Aging Workgroup, unpublished data).

**Process.** Our research protocol and evaluation tools were approved by UC Davis Office of Research Institution Review Board. An existing UC-approved food safety curriculum was adapted to reflect the needs and circumstances of the elderly and to effectively teach knowledge and skills to seniors, food handlers in senior programs and in-home caregivers. Cooperative Extension educators assessed and trained 696 participants from 10 counties (379 caregivers, 218 seniors and 99 food handlers) (fig. 2). Participants were from senior centers, senior food programs, in-home supportive services, and kinship caregivers. Ethnic composition of the study group was diverse (fig. 3), and the representation of seniors, food handlers and caregivers within each ethnic group is shown in figure 4.

**Data collection.** Baseline data were collected between January 2008 and March 2009 with an 11-question pre-test of food safety knowledge and practices; the same questions were asked in the post-test later. Participants ( $n = 696$ ) received 2 to 3 hours of interactive education in groups ranging in size from 10 to 22 participants. The education included information on the incidence of foodborne illness, which groups are at greater risk, causes and sources of foodborne illness, as well as the four basic components of food safety: cleanliness (personal hygiene, hand-washing and washing foods); proper cooking and chilling temperatures; keeping food at the right temperature and use of thermometers; and storing food to prevent cross contamination of raw and cooked meat or contamination by chemicals or objects.

Baseline food behavior data also were collected before the food safety education with a USDA-approved food behavior checklist that was filled out by 506 of the 696 study participants. The checklist contains 21 questions about meal planning, food buying, food safety practices, healthy food choices, food preparation practices, reducing salt and fat intakes, eating fruits, vegetables and whole wheat bread, food availability and food security, eating out, and eating breakfast.

**Data analysis.** The change in food safety knowledge as a result of the training was derived by comparing the pre-test and post-test scores of correct responses

# The Nutriture of People

From *The Yearbook of Agriculture* (USDA 1959), "The Nutriture of People"

**1959** "... Although more Americans over 60 own their own homes than do younger people, institutions for older persons also are increasing more rapidly than for any other age group.

"Institutional food service generally is planned to provide approximately the amounts of nutrients recommended for the largest group in the institution. Several studies between 1948 and 1956 of older groups in institutions have indicated however, that the daily meals, as served, may provide recommended amounts of nutrients, but the actual nutrient intake levels of the older individuals often are below the recommended amounts.



"This situation is not unlike comparisons of intake levels of families as a whole and of the individual members of families. Among the groups in large institutions, however, there is less consideration of individual food habits and food preferences in planning menus than there would be for family groups.

"Studies by the California, Florida, and Rhode Island Agricultural Experiment Stations between 1950 and 1956 indicated that the nutrient intake levels of older groups in institutions generally are substantially lower than the nutrient intake levels of older persons in individual homes. Most of the residents in public institutions consumed considerably less than recommended amounts of all nutrients. . . .

"When their intakes of iron and of protein were adequate, some relationship was evident between the intake of iron and protein and the hemoglobin. When intakes of iron and protein are generally high, hemoglobin levels may be rather consistent — an indication that hemoglobin beyond certain intake levels does not generally increase with higher intakes."

Nutritional Science and Toxicology, UC Berkeley



UC Professor Agnes Fay Morgan.

*Agnes Fay Morgan, co-author of the essay excerpted above, was a pioneer among women in American science. Morgan came to UC Berkeley's faculty in 1915. The next year, she became a founding co-chair of the Department of Home Economics. Two years later she was sole chair of the new Department of Household Science, within UC Berkeley's College of Agriculture. Her goal was to validate*

*or debunk common household customs of cooking, clean living and good order by scientific means, and in that way promote sound practices in this tradition-bound arena. Those who studied under Morgan were well qualified to teach science and nutrition courses, along with the cooking and sewing classes one might expect of a home economics graduate.*

*Morgan's service to the University has been recognized in many ways, including a special symposium held on the 50th anniversary of her joining the faculty and the naming of Agnes Fay Morgan Hall, UC Berkeley's nutrition building, in her honor.*



*A Celebration of Science and Service*

for individuals and the overall group. The *P* value for knowledge gain was derived by determining the probabilities of getting all answers correct for all the choices in the 11-question test. The pre-test null hypothesis — that is, the array of pre-test probabilities for correct answers — was determined by this formula:

If *n* = number of choices and *c* = number correct, then

$$P(c) = c!(n-c)!/n! \times 100\%$$

To construct a null hypothesis for the post-test, one must account for the effects

of the training intervention. In this study, it meant reducing the number of choices by counting each correct answer as “1”, which was selected because a larger integer eliminates choice for questions with just 2 possible correct answers. When choices are reduced by 1, the null hypothesis for each question (probability of correct answers by chance) increased by a certain percentage.

Baseline food behavior practices, from the food behavior checklist assessment, were entered into an Excel database, summarized, normalized and examined to

determine the baseline nutrition education needs of the participants. Results from different questions were grouped into acceptable behavior targets toward achieving larger nutrition goals such as reducing fat, salt and sugar in the diet.

## Baseline/pre-test results

Baseline food safety test results, before the training, show a serious need for basic food safety knowledge to help prevent foodborne illness among at-risk seniors. Many participants lacked correct information about cooking and cooling temperatures. For example, only 57% believed using a thermometer was the most accurate way to determine if foods are adequately cooked.

Pre-test data show more than 50% of the study group participants answered incorrectly six of the 11 food safety questions: 66% provided an incorrect response to the statement that “foodborne illness is not always caused by something eaten in the last 12 to 14 hours”; 64% believed, incorrectly, that appearance, odor and taste can determine if food is safe to eat; 65% did not know that food should be stored in shallow containers; 73% reported incorrect answers about chilling food when the temperature is less than 90°F and 34% when the temperature is over 90°F; 43% did not know that using a thermometer is the most accurate way to determine if food is accurately cooked; and 51% incorrectly identified the recommended refrigerator temperature. Also, many participants did not recognize the population groups at increased risk for foodborne illness: 70% identified older people as a group at risk but only 40% identified grandfathers; 40% knew that pregnant women are at risk; 45% identified diabetics as at risk; 46% knew people with chronic diseases are at risk; and 62% recognized people with weakened immune systems as being a vulnerable group for foodborne illness (table 1).

## Knowledge gain/post-test results

To assess the rate of knowledge gained from pre-test to post-test, a null hypothesis was derived that represented the difference between post-test and pre-test probabilities for correct answers. We used a chi-squared test to compare the actual knowledge gain to the expected (null hypothesis) knowledge gain. The comparison produced a probability (*P*)

TABLE 1. Correct pre- and post-test responses to food safety questions\*

Question	Pre-test	Post-test
	..... % .....	
1. Groups at highest risk for foodborne illness:		
young children	61	74
older adults	70	85
people with diabetes	45	67
people with chronic disease	46	67
people with weakened immune systems	62	69
pregnant women	40	66
grandfathers over 50 years of age	40	54
2. Foodborne illness is <i>not</i> always caused by something eaten in the last 12 to 14 hours.	34	64
3. Bacteria and viruses are the most common causes of foodborne illness.	65	72
4. Potential sources of harmful bacteria include		
homegrown produce	26	47
organic produce	25	45
commercial produce	39	55
raw meat or poultry	83	89
unwashed hands	76	89
insects	43	59
5. Appearance, odor, and taste <i>cannot</i> determine if food is safe to eat.	36	75
6. Washing hands with warm water and soap is recommended.	95	96
Washing raw meat and poultry with running water is <i>not</i> recommended.	13	65
Washing fruits and vegetables with running water is recommended.	93	94
Washing and sanitizing sink before and after food preparation is recommended to prevent cross contamination.	93	95
7. Using separate cutting boards for raw meat and fresh produce is recommended.	93	95
Discarding old cutting boards with many cuts and grooves is recommended.	86	94
Plates/platters/pans used to hold raw meat should be rinsed with running water before used to hold cooked meat (incorrect as written: rinsing is <i>not</i> sufficient to destroy bacteria).	15	20
Storing raw foods below cooked foods in the refrigerator is recommended.	71	81
8. Using a thermometer is the most accurate way to tell if meat/poultry is cooked safely.	57	73
9. Chilling foods within 1 hour if warmer than 90°F is recommended.	66	83
Chilling foods within 2 hours if cooler than 90°F is recommended.	27	51
10. Storing foods in shallow containers in the refrigerator is recommended.	35	77
11. Refrigerator temperature should be 40°F or below.	49	67

\* Study participants (*n* = 696) were comprised of 379 caregivers, 218 seniors and 99 food handlers.



value) that was at least as extreme as the null hypothesis (cut-off 0.05). Evaluation of the total group ( $n = 696$ ) found an average increase in the percentage of correct responses from 58.0% to 76.1%, a knowledge gain of 18.1% ( $P = 0.4930$ ). The gains of seniors (10.4%,  $P = 0.0404$ ) were much lower than those of the in-home caregivers (23.4%,  $P = 0.9045$ ) and food handlers (18.1%,  $P = 0.7195$ ) as shown in figure 5. By ethnicity,  $P$  values for knowledge gain were Native American  $P = 0.9966$ , Hispanic  $P = 0.9960$ , Caucasian  $P = 0.7681$ , Bi-ethnic/Multiracial  $P = 0.6846$ , African American  $P = 0.6060$ , and Asian/Pacific Islander  $P = 0.0031$  (fig. 6). The size of the Native American and Bi-ethnic/Multiracial groups were comparatively small, 9 and 19 participants, respectively, but all ethnic groups had significant gains in knowledge at different rates except for Asian/Pacific Islander ( $P = 0.0031$ ).

### Baseline food/nutrition behaviors

Table 2 summarizes the baseline food behaviors of the 506 study participants who completed the food behavior checklist. Of significance are the questions about food insecurity — 46% often worried about running out of food, 10% reported that they actually ran out and 31% felt it was too expensive to eat a lot of nutritious food. The research team grouped a series of baseline healthy behaviors into target goals under the areas listed in

table 2. The performance of the group in relation to these goals was determined by Boolean analyses to detect deterministic dependencies between observed response patterns. Baseline performances of the study group to meal planning and shopping target goals are displayed in figure 7.

### Training needs, considerations

In the food safety knowledge pre-test, the MFSFS research team found food safety practices similar to the findings of a national representative survey ( $n = 1,140$ ); older adults think they are knowledgeable about food safety but do not follow recommended food safety practices (Cates et al. 2009). Dutram et al. (2002) reported food safety education improved safe food-handling practices among low-income elders participating in congregate meal programs and home-delivered meal programs. The MFSFS post-test results point to a similar conclusion. The national study of older people by Cates et al. (2009) suggested men in particular and individuals with high income or education levels also need food safety education.

The positive findings in the MFSFS study were that in the pre-test 66% knew cooked food should be refrigerated within 1 hour if the temperature is over 90°F, and 67% knew the correct refrigerator temperature at post-test. Of most concern was the lack of knowledge about cross contamination of raw and cooked meat, potential



At a food safety training in Davis, Calif., participants used a GlitterBug UVA lamp to find out how thoroughly they washed their hands.

sources of harmful bacteria, proper use of a thermometer to accurately determine if food is adequately cooked (some used taste, smell and appearance to determine if food is safe) and the increased risk with age for foodborne illness. By groupings, seniors knew relatively less than the food handlers or caregivers.

The research study was limited to a convenient sample of 696 people. Therefore, the results are not derived from a population-based sample, but they may point to the need for food safety as well as nutrition education among participants in UC Cooperative Extension's Nutrition, Family and Consumer Sciences programs.

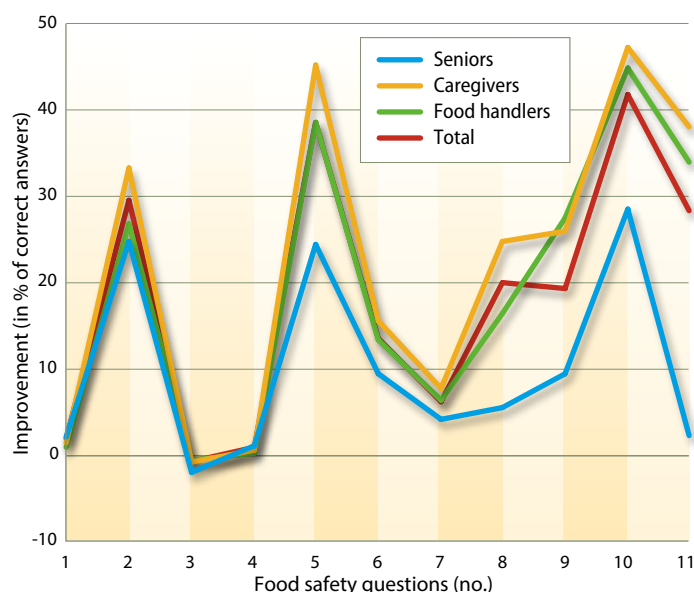


Fig. 5. Knowledge gained from pre-test to post-test. Study group was comprised of 218 seniors, 379 caregivers and 99 food handlers (from church communities and food pantries). A chi-squared test was used to compare the actual knowledge gain to the expected knowledge gain.

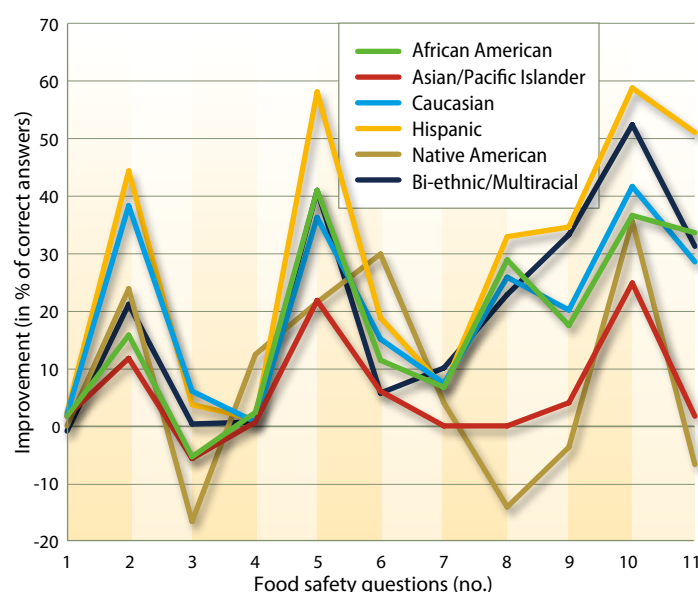


Fig. 6. Knowledge gained from pre-test to post-test by ethnicity.

TABLE 2. Baseline food behaviors of participants, before training		
Food behavior areas	Specific behaviors	Percentage of participants
Meal planning and shopping	Planned meals ahead	47%
	Prepared a shopping list	62%
	Compared prices	73%
Considerations of healthy food	Thought about healthy foods when they made food selections	83%
	Read food labels	57%
	Chose foods low in salt or cooked with less salt	46%
	Usually ate foods low in fat	62%
	Chose low-fat milk	62%
	Removed fat from chicken	65%
Fruit, vegetables and whole grain practices	Usually ate more than one kind of fruit each day	57%
	Ate more than one kind of vegetable each day	62%
	Usually selected whole wheat bread	73%
Food insecurity	Ran out of food before the end of the month	10%
	Often or usually worried about running out of food before they could buy more food	46%
	Strongly agreed or agreed that it was too expensive to eat a lot of nutritious foods	31%
Food safety	Did not leave meats and dairy out of the refrigerator more than 2 hours	69%
Eating out	Ate in restaurants an average of	1.59 times/week
Soda consumption	Usually or often drank regular sodas each day	19%

*n* = 506: All participants combined.

Key to the effectiveness of food safety education among elders is the method of information delivery. Kosa et al. (2011), in a randomized control evaluation of the effectiveness of Web-based and print materials with older adults, found no significant differences between the two delivery methods. They suggested focusing education on a limited number of practices and combining print materials with personal contacts.

The MFSFS training used a client-centered, senior-friendly, interactive and hands-on educational approach, which achieved an average knowledge gain of 18.1%. Interactive education has been used very successfully in the Alameda County Quality of Life education program since 1993, and most recently in the 2012 Staying Healthy nutrition education program, completed by over 260 senior-housing residents with a graduation rate higher than 95%.

The research findings suggested the levels of knowledge retention differed among the three groups (seniors, food handlers, caregivers). The caregivers (some were much younger than the seniors) as well as the food handlers may have had some or more exposure to food

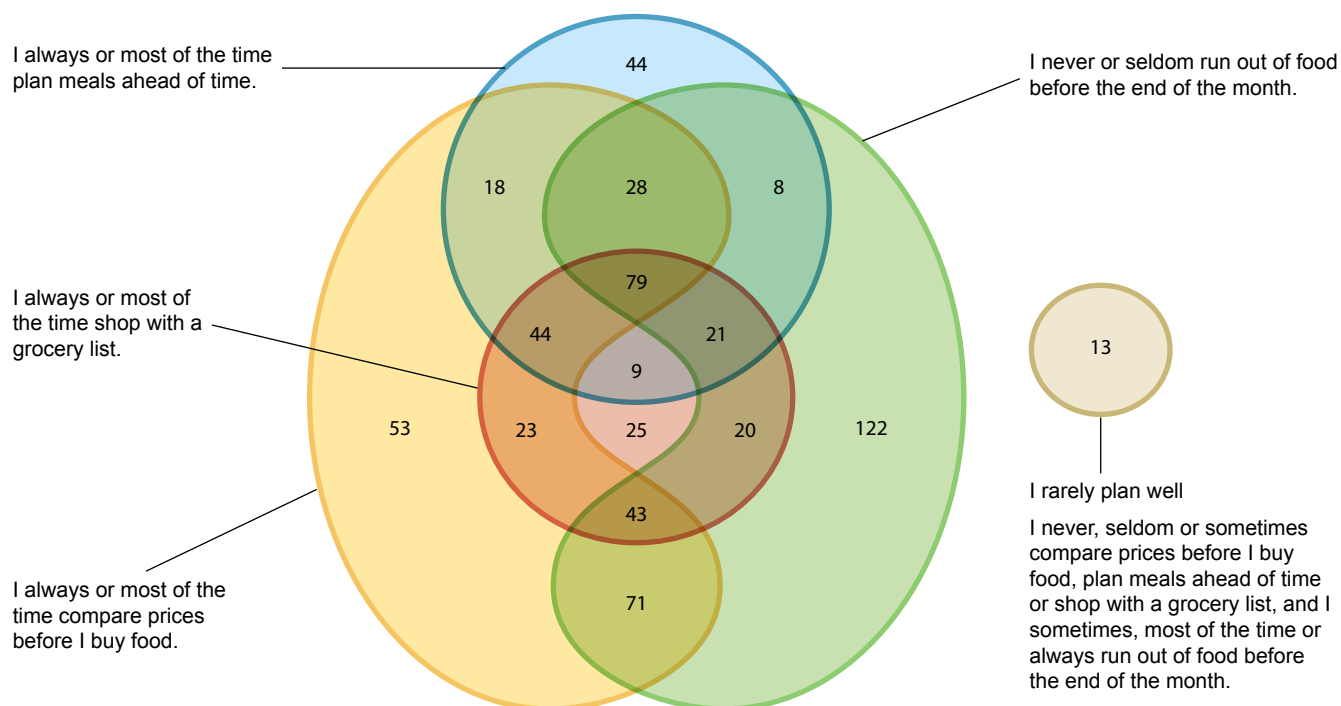


Fig. 7. Learning targets for good meal planning and shopping behavior goals, and the number of participants in the study group (*n* = 621) achieving them: 2.09% of the participants achieved no target (rarely plan well); 39.29% achieved one; 23.99% two; 21.90% three; and 12.72% all four targets.



safety information than the seniors. Research shows that older adults with prior knowledge of health information can retain it at levels that resemble those of young adults (Miller et al. 2013). Other research shows that with age, certain normal changes occur with the loss of episodic memory that might impact comprehension and knowledge retention (Ober 2010).

For older adults with low knowledge and those with low literacy, training must be tailored to fit individual learning needs (Miller 2010).

### Potential for new curriculum

A 2008 statewide meeting of the ANR Umbrella Nutrition Workgroup voted a caregiver curriculum and training program to be a priority, and the 2010 special issue in *California Agriculture* on aging stated the need to assess the unique nutrition and wellness needs of aging Californians (Blackburn et al. 2010). Our research supports the need for training older adults and those who prepare their food to address food safety needs in the home and community. The training must seek to increase a) declarative and procedural knowledge surrounding

food safety standards and b) skills surrounding how to apply those standards to ensure safe food preparation and storage. Importantly, the training also must be tailored to those most at risk for foodborne illness.

The data collected by the research team, described here, provides a knowledge base that could be used for Cooperative Extension nutrition and food safety curricula for seniors and caregivers in California and also to heighten awareness of the food safety needs of California's elders. The researchers have distributed this information through UC Delivers, a UC ANR website (<http://ucanr.edu/delivers/>), and through conference presentations, peer-reviewed publications, national award applications, and educational interventions with providers and seniors in some counties. An outreach strategy is needed to disseminate the learning and the need for senior-friendly food safety and nutrition information statewide and nationally. In the long term, the MFSFS data and lessons learned could be used to develop a comprehensive UCCE nutrition, wellness and food safety curriculum for at-risk seniors and caregivers in California.

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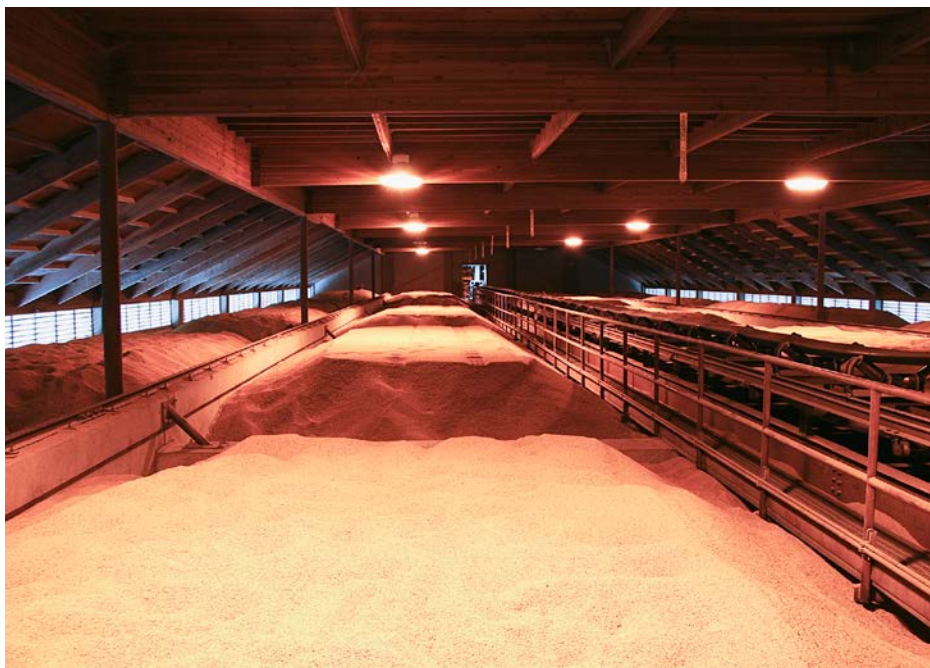
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# Survey of rice storage facilities identifies research and education needs

by Luis A. Espino, Chris A. Greer, Randall G. Mutters  
and James F. Thompson

*More than 40 million hundredweights of rice are produced in California's Sacramento Valley every year. After harvest, the rice is stored in facilities on-farm or off-farm until it is transported to mills or to ports for export. We conducted a survey of storage operations to characterize grain storage and pest management practices to guide future UC Cooperative Extension research efforts. The results indicate that grain moisture content, temperature and insect pest management are the most important challenges for both on- and off-farm storage operations. Survey responses show high adoption of integrated pest management programs, with most storage operations relying on monitoring, thresholds, sanitation and aeration to manage pest problems. Fumigant use was reported more frequently in off-farm storage operations than on-farm operations. Cooperative Extension educational efforts should focus on grain and temperature monitoring, insect identification and safe use of fumigants. Research is needed to improve management of grain temperature and moisture content, and insect infestations.*

Rice is one of the most important crops in California's Sacramento Valley. Approximately 500,000 acres are planted annually (Hill et al. 2006). From 2000 to 2011, California produced an average of 43.4 million hundredweights (cwt, 1 cwt = 100 pounds) of rough rice (unprocessed rice that includes hull and caryopsis) per year. After harvest, rice is dried and stored either on-farm or at commercial drying and storage facilities off-farm. Rice is typically harvested when grain moisture content is between 18% and 22%. To preserve its quality and allow long-term storage, rice needs to be dried down to 13% to 14%



Randall Mutters

A UC Cooperative Extension survey of stored-rice management practices in California's major rice-producing counties found that keeping rice at the appropriate moisture content and temperature and free of insect infestations are the most important challenges operators face.

moisture content (Mutters and Thompson 2009).

Most on-farm storage facilities use metal bins of various capacities for drying and storage; the rice is dried using outside air. Off-farm storage facilities use column dryers to dry rice to 16% or 17% moisture content and finish the drying in storage structures using outside air (Kunze and Calderwood 1985; Mutters and Thompson 2009). In some cases, large farming operations own a column dryer and receive rice from other farmers for drying and storage.

California rice is stored as rough rice until it is shipped for milling. Rice needs to be maintained at an appropriate temperature and moisture content to preserve its quality. In addition, it needs to be protected from damage by insects and other pests, such as rodents and birds. Insect infestation during storage can reduce the selling price by negatively affecting the rice grade, determined by the percentage of insect-damaged kernels, or by causing the rice to be classified as "infested" if live insects are found in a sample (USDA FGIS 2002). Insect activity can also increase grain temperature and promote

the growth of microorganisms that cause spoilage and reduce the quality of the rice. High grain temperatures and moisture may also cause odors that further reduce the value of the rice.

Fumigants are commonly used to prevent or eliminate insect infestations during rice storage. During 2010, 8.5 million cwt of rice were fumigated in California, using 12,327 pounds of fumigant active ingredients (DPR 2011). Prior to our survey, the extent to which other management practices, such as monitoring, sanitation and aeration, are used in stored rice was unknown.

To determine how the industry manages the storage of rough rice and its use of integrated pest management (IPM), we conducted a mail survey of rice producers and commercial facilities that store rough rice. We collected baseline information regarding storage infrastructure, grain and pest management practices and economic impacts of pest problems. Our goal was to gather information that would help

Online: <http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v068n01p38&fulltext=yes>  
doi: 10.3733/ca.v068n01p38



**TABLE 1. Number of survey responses per county, sum of reported rice acreage (on-farm operations only) and stored rice (cwt) per county, and comparison to the county's total rice acreage and production\***

County	On-farm operations					Off-farm operations		
	<i>n</i>	Survey-reported acreage	% of 2010 county harvested acreage	Survey-reported stored rice	% of 2010 county production	<i>n</i>	Survey-reported stored rice	% of 2010 county production
		<i>acres</i>	<i>%</i>	<i>cwt</i>	<i>%</i>		<i>cwt</i>	<i>%</i>
Butte	1	273	0.29	3,000	0.04	4	5,544,000	69.53
Colusa	11	10,810	7.13	544,650	4.48	12	7,406,522	60.96
Glenn	12	9,017	10.62	551,400	8.41	1	923,000	14.07
Sutter	5	3,860	3.37	415,000	4.51	7	5,536,307	60.18
Yolo	1	4,200	10.34	95,424	3.03	5	5,618,000	178.35
Yuba	1	281	0.73	74,408	2.46	0	—	—
<b>Statewide</b>	<b>31</b>	<b>28,441</b>	<b>5.14</b>	<b>1,683,882</b>	<b>3.80</b>	<b>29</b>	<b>25,027,829</b>	<b>56.46</b>

\* Source: USDA NASS 2012.

determine UC research and Cooperative Extension education priorities for stored-rice management in California.

## Survey

Contact information for rice growers who have on-farm storage facilities was obtained from UC Cooperative Extension farm advisors and county agricultural commissioner's offices in the major rice-producing counties of California. Contact information for commercial rice dryers and warehouses was obtained from the 2009–2010 California Warehouse Association directory. A draft questionnaire was circulated among a small subset of representative storage operators and UC personnel familiar with the industry to improve the clarity and relevance of the questions. Once finalized, the questionnaire consisted of a 10-page booklet that included instructions, 29 questions and space for comments (see sample questionnaire at <http://ucanr.edu/u.cfm?id=88>). The instructions directed respondents to answer the questions based on their experiences during the 2010–2011 storage period (storage of the 2010 harvest) unless otherwise indicated in the question.

The survey protocol was approved by the UC Davis Institutional Review Board. Survey implementation followed the recommendations of Dillman et al. (2009). Briefly, pre-notice letters informing recipients that they would be receiving a survey were mailed to 134 contacts on Jan. 3, 2012. Detailed letters explaining the objectives of the survey, questionnaires and pre-stamped, self-addressed return

envelopes were mailed on Jan. 6. Thank you/reminder postcards were mailed on Jan. 17. Reminder letters, questionnaires and pre-stamped, self-addressed return envelopes were mailed on Feb. 3 to contacts who had not returned the questionnaire by that date.

Of the 134 contacts, 10 returned the survey noting that they did not store rice and 8 surveys were returned by the U.S. Postal Service as undeliverable. As a result, surveys were received by 116 valid contacts. Of these, 61 returned completed questionnaires between January and April, a return rate of 53%. Not all respondents answered all the questions; the number of respondents for each question is indicated in the results.

Respondents who reported farming rice and using on-farm storage bins but not owning a column dryer were classified as on-farm storage operations; respondents who reported not farming rice were classified as off-farm storage operations. Respondents who reported farming rice and owning a column dryer were classified as on-farm operations if

they stored no more than 125% of their production potential, calculated as acreage reported times 80.2 cwt, the average rice yield per acre in California for 2010 (USDA NASS 2012); otherwise, they were classified as off-farm operations.

Responses were received from all major rice-producing counties of California (table 1). The sum of all rice acreage and storage reported by on-farm operations represents a small fraction of the total acreage and rice produced in California in 2010. The sum of all rice stored reported by off-farm operations represents more than half of 2010 California rice production.

The amount of rice stored per operation varied greatly. On average, on-farm operations ( $n = 28$ ) reported storing 60,100 cwt of rice. The quantities stored ranged from 3,000 to 230,000 cwt. Off-farm operations ( $n = 26$ ) reported storing between 65,000 and 4.1 million cwt of rice, with an average of 962,600 cwt.

Total on- and off-farm stored rough rice reported in the survey represented 60% and 69%, respectively, of the USDA's

**TABLE 2. Average number of rice storage structure types, their total capacity and the amount of total rice stored during the 2010–2011 storage period, per operation, Sacramento Valley**

Structure type	On-farm operations ( $n = 32$ )			Off-farm operations ( $n = 29$ )		
	Number	Total capacity	Total rice stored	Number	Total capacity	Total rice stored
		<i>cwt</i>	<i>cwt</i>		<i>cwt</i>	<i>cwt</i>
Round metal bins	10	64,105	56,129	25	337,698	300,941
Concrete silos	0	0	0	17	185,796	168,896
Flat warehouses	0	0	0	2	532,798	519,238



In California, after harvest, rice is stored in metal bins, *top*; concrete silos, *middle*; and flat warehouses, *bottom*. Round metal bins are typical in on-farm storage operations, while all three structures are common in off-farm operations. During the 2010–2011 storage period, on- and off-farm storage operations used on average 81.6% and 89.5%, respectively, of their storage capacity.



estimate (USDA NASS 2012) of rough rice stored on- and off-farm by Dec. 1, 2010, respectively, demonstrating that our survey included operations that account for a large proportion of the rice stored in the Sacramento Valley.

### Storage structures, systems

Three types of structures are used in California to store rice: metal bins, concrete silos and flat warehouses. After harvest, rice may be put in bins and dried using outside air. This type of drying, known as bin drying, is widely used by on-farm operations (Kunze and Calderwood 1985). Alternatively, rice can be dried by using heated air first, followed by ambient air. Using a column dryer, rice is dried to 16% or 17% moisture content and then transferred to bins, silos or flat warehouses, where the drying process continues, with outside air, to achieve the final 14% moisture content. This combination system is typically used by commercial rice dryers in California (Kunze and Calderwood 1985).

The main structure type used by on-farm storage operations that responded to the survey is round metal bins (table 2). Off-farm operations reported round metal bins, concrete silos and flat warehouses. During the 2010–2011 storage period, on- and off-farm storage operations used on average 81.6% and 89.5%, respectively, of their storage capacity.

To preserve the quality of rice during storage, managers need to keep it at an appropriate temperature and moisture content. For this, outside air is regularly forced through the grain mass. The decision to aerate is based on the temperature and moisture content of the grain (Mutters and Thompson 2009; Steffe et al. 1980). Managers start or stop



The rice weevil (A), lesser grain borer (B) and red flour beetle (C) were selected by the majority of survey respondents as insects causing problems in stored rice.



fans manually when conditions are appropriate to dry and maintain rice at the desired temperature and moisture content. Alternatively, an aeration controller system can be used to automatically start and stop fans. Our survey shows that aeration controller systems are uncommon. Only one on-farm and eight off-farm operations reported having an aeration controller system.

Grain temperature can be assessed using hand-held thermometers, temperature probes or temperature cables. Hand-held thermometers can measure the temperature of the grain mass surface or of a sample extracted from the grain mass using a grain probe. Temperature probes can be inserted into the grain mass to determine the temperature of the grain at a certain depth. Temperature cables are sensors suspended from the roof of a storage structure that run nearly to the floor of the structure; the number of cables in a structure varies with the structure's size. Temperature probes and cables allow managers to detect grain temperature changes at different grain depths without having to extract samples from these depths. Most of the operations replying to our survey report monitoring grain temperature during storage (see below, "Aeration"). The majority of on-farm operations ( $n = 23$ ) report using a hand-held thermometer (52.2%), while most off-farm operations ( $n = 24$ ) report relying on temperature cables within storage structures (79.2%).

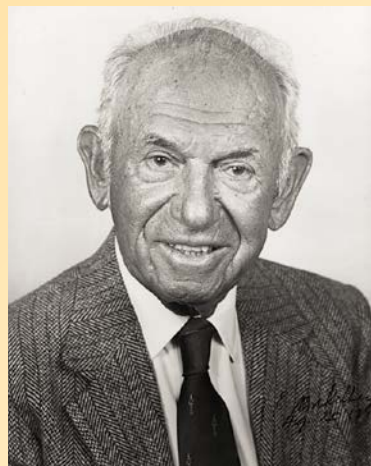
### Storage problems

Survey respondents were asked to choose and rank the three most important rough rice storage problems they experienced during the past 5 years from a list of six potential problems (fig. 1). For each respondent, the problem ranked as most important, second most important, and third most important received a score of 3, 2 and 1, respectively, and problems that were not ranked received a score of 0. Then, for each problem, the average and relative scores were calculated. A problem's relative score was determined by dividing the problem's average score by the highest possible average score (3). For on-farm operations, maintaining appropriate grain moisture is one of the most important problems respondents faced, followed by insects and grain temperature. For off-farm operations, one of the most

## Early grain storage research

**1947** "Many insects that infest grain in farm storage are small. Some are smaller than a grain of wheat. In fact, with some species, a single kernel of grain furnishes sufficient food for the development of from one to several individuals.

"Among the more important pests are the granary weevil, rice weevil, lesser grain borer, Angoumois grain moth, confused flour beetle and the saw-toothed grain beetle. The first four mentioned are capable of attacking and destroying sound grain. The others generally feed upon broken grains, particularly the finer particles.



"Where the environment is favorable, these insects cause serious damage and under extreme conditions the grain may be completely destroyed. Most of the important grain pests are widespread throughout California and if grain is not properly protected it is subject to heavy infestation.

"The development of stored grain pests is largely regulated by temperature and the moisture content of the food on which they feed. The most favorable temperature range is from 80 to 85 Deg. F; while the most ideal moisture content of the food ranges from 13 to 17 per cent."

## Dryness Protects Farm Stored Grain From Insect Attack

A. E. Michelbacher

Many insects that infest grain in farm storage are small. Some are smaller than a grain of wheat. In fact, with some species, a single kernel of grain furnishes sufficient food for the development of from one to several individuals.

Among the more important pests are the granary weevil, rice weevil, lesser grain borer, Angoumois grain moth, confused flour beetle and the saw-toothed grain beetle. The first four mentioned are capable of attacking and destroying sound grain. The others generally feed upon broken grains, particularly the finer particles.

Where the environment is favorable, these insects cause serious damage and under extreme conditions the grain may be completely destroyed. Most of the important grain pests are wide-spread throughout California and if grain is not properly protected it is subject to heavy infestation.

### Development of Stored Grain Pests

The development of stored grain pests is largely regulated by temperature and the moisture content of the food on which they feed. The

At the time of this writing, author Abraham E. Michelbacher was assistant professor of entomology and assistant entomologist at the Agricultural Experiment Station at UC Berkeley. He went on to become a full professor and leader in UC Berkeley's Department of Entomology, as well as a pioneer in the fields of biological pest control and the specifically targeted use of pesticides. After retirement in 1960, he was named professor emeritus and continued his research and Extension work for nearly 30 years more. Michelbacher died in 1991, aged 92.



A Celebration of Science and Service

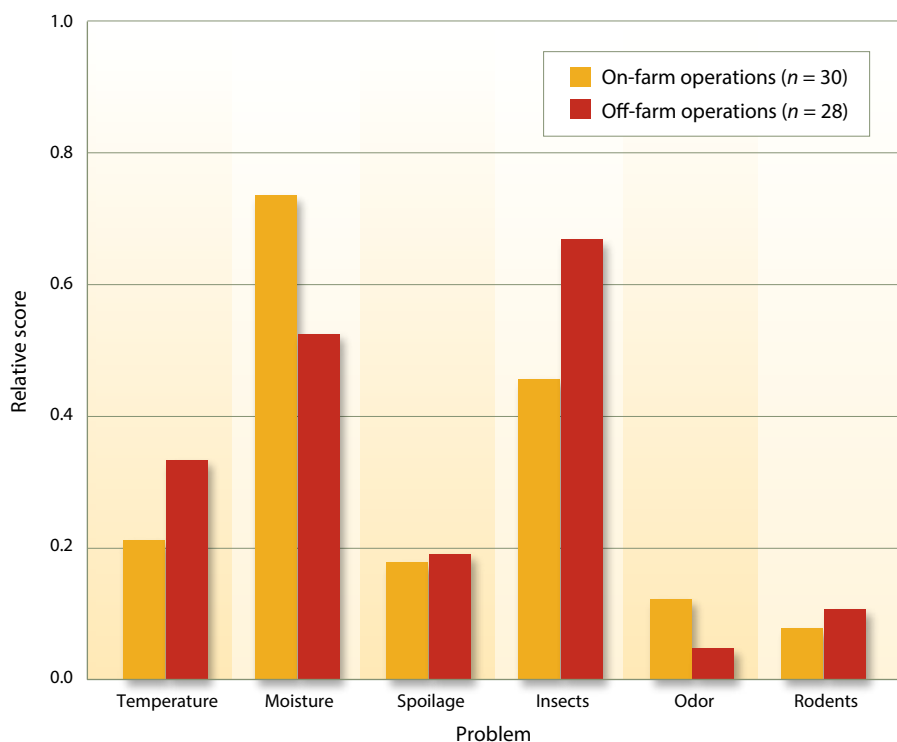


Fig. 1. Relative score of problems important to rice storage operations in the past 5 years. A problem's relative score was determined by dividing the problem's average score by the highest possible average score (3).

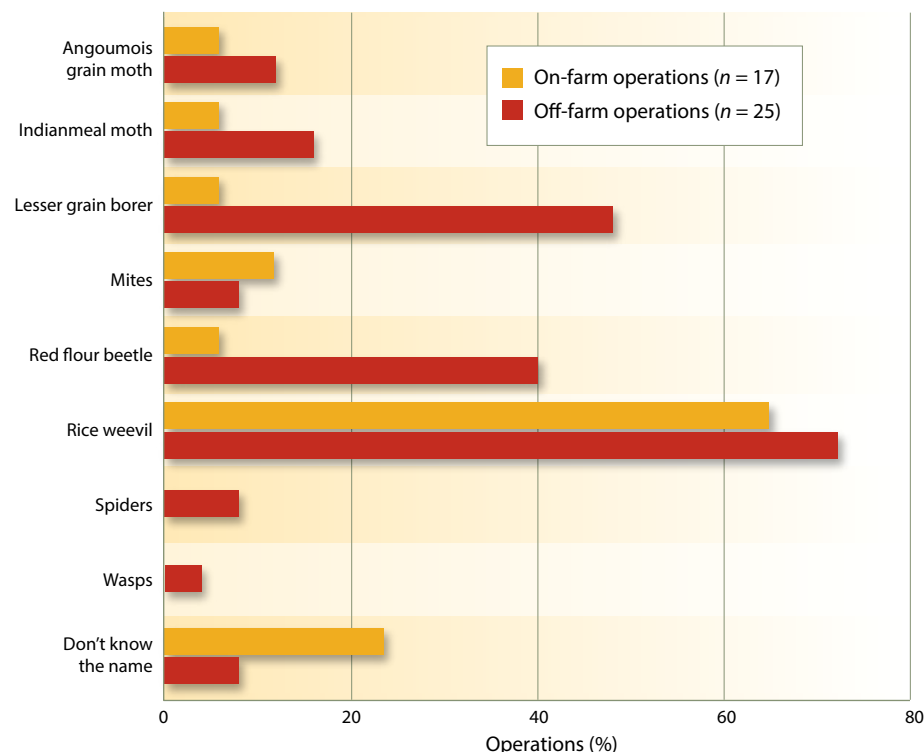


Fig. 2. Percentage of operations that named one of the following arthropods as causing problems in stored rough rice in the past 5 years: Angoumois grain moth, *Sitotroga cerealella* (Olivier); Indianmeal moth, *Plodia interpunctella* (Hübner); lesser grain borer, *Rhyzopertha dominica* (Fabricius); mites; red flour beetle, *Tribolium castaneum* (Herbst); rice weevil, *Sitophilus oryzae* (Linnaeus); spiders or wasps. Respondents were given the option to select "I don't know the name of the insects."

important problems is insect infestation, followed by maintaining appropriate grain moisture and temperature.

Operations that chose insects as a problem were asked to name up to three insects that caused problems in the past 5 years; respondents could also select the option "I don't know the name of the insects." More than 60% of on-farm operations named the rice weevil, *Sitophilus oryzae* (Linnaeus), and more than 20% indicated that they did not know the name of the insects (fig. 2). More than 70% of off-farm operations named the rice weevil, and more than 40% named the lesser grain borer, *Rhyzopertha dominica* (Fabricius), and red flour beetle, *Tribolium castaneum* (Herbst). Only a small proportion of off-farm operations indicated not knowing the name of the insects.

When asked what actions are likely to be taken if insects become a problem during storage, the majority of operations selected fumigation (table 3). Aeration was the second most selected option. On-farm operations respondents who selected the "other" category explained that they had never had a problem with insects.

## Monitoring

Stored rice should be inspected to determine its temperature, moisture content and sanitary condition throughout the storage period (Howell 2003). In our survey, almost all operations (97%,  $n = 61$ ) reported inspecting rice during storage. Only two on-farm operations reported not conducting inspections.

Stored-rice monitoring guidelines recommend that storage operators inspect

TABLE 3. Percentage of operations that selected an action to be taken if insects were found infesting stored rice

Action	On-farm operations (n = 31)	Off-farm operations (n = 29)
	..... % .....	
Aerate grain	22.6	37.9
Spray surface of grain mass	3.2	0.0
Spray area around storage	9.7	20.7
Fumigate grain	90.3	96.6
CO <sub>2</sub> treatment	3.2	3.4
Heat treatment	0.0	3.4
Other	12.9	0.0

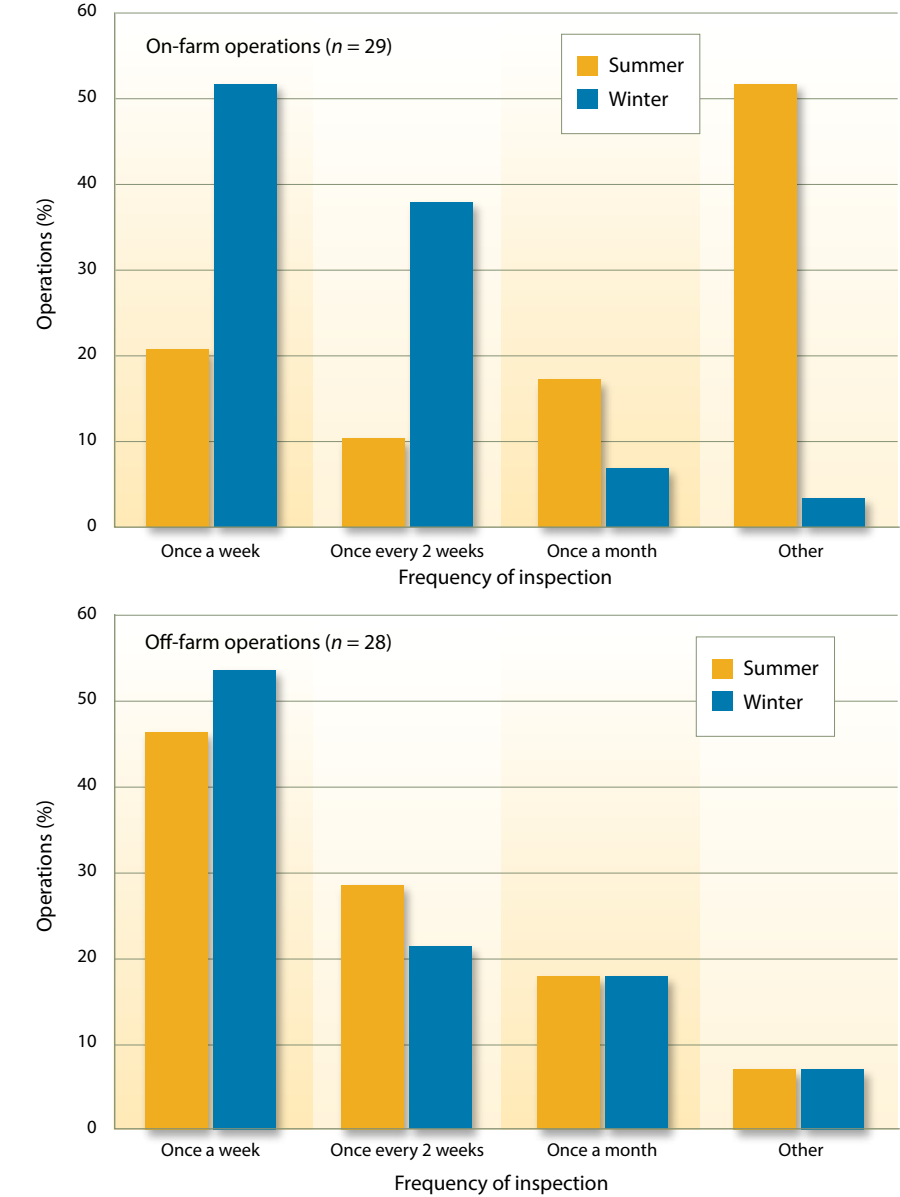


rice twice a month when temperatures are below 60°F and weekly when temperatures are above 60°F (Mutters and Thompson 2009). In our survey, operators were asked how frequently they inspected their rice during winter and summer. For summer, half of on-farm operators selected “other” as their frequency of inspection (fig. 3). These operators explained that grain is usually taken out of storage before summer and therefore summer inspections were not conducted. Of those keeping rice during the summer months, inspections were made once a week, once every 2 weeks or once a month in very similar proportions. For winter, most on-farm operations reported inspecting their rice once a week or every 2 weeks. One on-farm operator selected “other” and explained that the operation only inspects rice after rainstorms.

For off-farm operations, the percentage of responses for each frequency of inspection was similar during summer and winter. Most off-farm operations reported inspecting rice once a week, followed by once every 2 weeks and once a month. Off-farm operations respondents who selected the “other” category explained that their storage time was very short, usually less than a week, and therefore they did not need to inspect grain frequently.

On-farm operations (*n* = 29) indicated that the most common methods of inspecting rice were looking at the surface of the grain mass (72.4%), inspecting samples taken with a probe (72.4%) and inspecting samples scooped from the surface of the grain mass (58.6%). Off-farm operations (*n* = 28) reported inspecting the grain surface (78.6%), using a grain probe (75%) and using the temperature of the grain as an indicator of pest activity or spoilage in the grain (64.3%). Most operations (79.3%) used more than one method to inspect rice.

Of all respondents, two-thirds reported using a guideline or rule to determine if insects were a problem during storage, and significantly more off-farm operations than on-farm operations indicated doing so (table 4). These responses indicate that 50% of the on-farm operations and 20% of the off-farm operations replying to the survey rely instead on subjective measures or experience to determine when an insect infestation becomes a problem.



**Fig. 3. Percentage of operations that indicated conducting inspections once a week, once every 2 weeks and once a month.**

TABLE 4. Percentage of operations implementing pest management actions during the 2010–2011 storage period			
	On-farm operations	Off-farm operations	All
	..... % .....		
Uses insect guideline*	53.3 (n = 30)	81.5 (n = 27)	66.7
Uses insect traps*	13.3 (n = 30)	37.9 (n = 29)	25.4
Monitors rice temperature	76.7 (n = 30)	85.7 (n = 28)	81.0
Applies a fumigation treatment*	26.7 (n = 30)	89.7 (n = 29)	57.6
Treats structures with an insecticide before filling them with grain	73.3 (n = 30)	79.3 (n = 29)	76.3
Applies an insecticide to the area surrounding storage structures	60.0 (n = 30)	72.4 (n = 29)	66.1

\* Significant differences between on- and off-farm operations, using chi-square test ( $\alpha = 0.05$ ).

Insect trap use is recommended inside and around grain structures to detect the presence of damaging insects in or around the grain and determine their spatial and temporal distribution (Hagstrum 2000). Insect trap use was relatively uncommon among the operations that responded to the survey (table 4), with a significantly higher proportion of off-farm operations using insect traps than on-farm operations. The limited use of insect traps may be due to cost, time needed to install and service the traps and lack of skills to identify the trapped insects.

### Pest management practices

**Sanitation.** Sanitation is the most cost-effective way to manage storage pests (Cogburn 1980). The elimination of grain, dust and other residue where insects survive while storage structures are empty reduces the potential for infestation of newly stored grain. In our survey, a large proportion of operations (93%,  $n = 59$ ) reported thoroughly cleaning their storage structures before storing new rice. However, almost 7% of respondents indicated not doing so. Although this proportion is low, it shows further improvement in the adoption of sanitation practices is possible. Emphasis on sanitation during training of operators may help increase adoption. A large proportion of operations indicated cleaning up spills and grain residue (98%,  $n = 59$ ), vegetation and animal debris (97%,  $n = 59$ ) around their storage structures.

Insecticide applications on the inside surfaces of storage structures kill insects that remain inside the structures while they are empty. This seems to be a common practice among both on- and off-farm operations (table 4). Spraying an insecticide in the area surrounding the storage structure if insects were found to be a problem during rice storage was a practice identified as likely to be implemented (table 3), and more than half of the survey respondents used insecticides in this way. Since areas around storage structures are sometimes treated on a calendar basis, the proportion of operations actually taking this action is higher than the proportion of operations that reported this as a likely action if an insect infestation was found (tables 3 and 4).

**Aeration.** A practice identified as likely to be implemented if insects were found to be a problem during rice storage was

aeration (table 3). When rice reaches temperatures between 70°F and 90°F, the risk of insect damage is increased (Mutters and Thompson 2009; Steffe et al. 1980). Managers can aerate to reduce grain temperature, thus reducing the likelihood of insect infestation. Also, by monitoring grain temperature, managers can find hot spots, areas where insect or microorganism activity causes the grain temperature to increase. The proportions of on- and off-farm operations that reported monitoring grain temperature during storage were similar (table 4). The proportion of operations that reported not monitoring temperature is close to 20%.

**Fumigations and insecticide use.** A large majority of on-farm operations identified fumigation as a likely action to be implemented if insects were found to be a problem during storage (table 3). During the 2010–2011 storage period, approximately one-quarter reported fumigating the grain (table 4). Most off-farm operations reported fumigation as an action to be taken if insects were found infesting grain (table 3) and, in fact, most reported fumigating some or all of their stored rice during the 2010–2011 storage period (table 4). The majority of these operations (81%) reported that fumigation was conducted because insects were found during



Randall G. Mutters

Stored rice should be inspected to determine its temperature, moisture content and sanitary condition throughout the storage period. In the authors' survey, almost all operations reported inspecting rice during storage. Above, a warehouse operator uses a grain probe to sample rice in a flat warehouse.



sampling of stored rough rice. Only 15% of operations that fumigated grain indicated that fumigations are always conducted at some time during storage or before moving rice out of storage.

Proper and safe application of fumigants requires highly skilled operators (Cogburn 1985; Howell 2003). In

California, some operations use their own employees to conduct fumigations, while others hire commercial fumigation services. In our survey, 54.5% and 45.5% of operations that fumigated during the 2010–2011 storage period reported doing the fumigation themselves or hiring a commercial fumigation service,

respectively. The cost of fumigation reported varied considerably. Eight on-farm operations reported costs that ranged from \$550 to \$30,000, with a mean of \$6,255 per operation, and 23 off-farm operations reported costs that ranged from \$900 to \$133,020, with a mean of \$19,528 per operation.

The use of insecticides as protectants (insecticide applications to grain as it is put into storage or to the top layer of the grain mass during storage) has been recommended to prevent insect infestations of stored rice (Cogburn 1985; Howell 2003). In our survey, none of the respondents indicated treating the grain with an insecticide as it is put into storage.

### Extension and research needs

Several conclusions regarding grain and pest management can be drawn from the results of our survey. First, on- and off-farm operations face similar issues during rice storage. Keeping rice at the appropriate moisture content and temperature and free of insect infestations seem to be the most important challenges. Insects are perceived as a more important problem by off-farm operations. This is probably because off-farm operations store larger amounts of rice and are more likely to store rice during the summer, when conditions are more favorable for insect development.

Second, results show that most storage operations inspect grain during storage, monitor temperature, use insect thresholds, and conduct sanitation and aeration as means to manage storage problems. All these practices are part of an IPM program of stored grain, indicating that IPM adoption among storage facilities in the Sacramento Valley is high.

Third, fumigant use is relatively low among on-farm operations and high among off-farm operations. For both types of operation, managers are more inclined to respond to insect infestations with fumigants than with other management methods.

Several aspects of rice storage in California, including pest management, can be improved through Cooperative Extension activities directed at storage operations. Close to 20% of operations responding to the survey reported not monitoring the temperature of the grain during storage. Because grain temperature can affect the quality of the grain as

Luis Espino



Luis Espino



A fourth of the operations responding to the survey indicated using insect traps. Traps can be used to monitor insect populations and anticipate problems. *Top*, sticky trap with pheromone lure, *inset*, for capture of flying insects. *Above*, probe trap for capture of insects moving in the grain mass.

well as the development of insect infestations, managers should be encouraged to include temperature monitoring in their programs. Our survey also showed that a large proportion of operations do not monitor rice during the summer months as frequently as it is recommended. Managers need to understand the effects of high temperature on insect populations and the importance of early detection of insect infestations.

**Currently, research in stored-rice management in California is very limited. Our survey indicates that operations would benefit from research to improve management of grain moisture content, temperature and insect infestations.**

More than 20% of on-farm operations that recognized insects as a problem indicated that they did not know the name of the insects causing problems. Managers need to be trained in stored-rice insect identification so they can differentiate between arthropods that pose a threat to stored rice and those that are only incidental. Only a quarter of operations responding to our survey indicated that they use insect traps. The use of traps could be encouraged as an effective way to monitor insect populations. Although the use of insect thresholds is high among off-farm operations, only half of on-farm operations report using one. By promoting monitoring and insect identification, on-farm operations may be more likely to adopt insect guidelines.

Finally, slightly more than half of respondents reported conducting their own fumigation. Training on the safe handling and application of fumigants should be offered to these operations.

Since 2000, UC Cooperative Extension has organized the Rice Quality Workshop, a 1-day training session where storage managers are trained in best management practices to preserve grain quality. This workshop is highly popular among managers, and it is usually held at full capacity. Needs identified by our survey can be addressed by strengthening or incorporating content in the workshop.

Currently, research in stored-rice management in California is very limited. Our survey indicates that operations would benefit from research to improve management of grain moisture content,

temperature and insect infestations. For example, insect traps could be used to facilitate insect monitoring, allowing managers to detect problems early, before deterioration occurs. Guidelines for their use in different storage structures could be developed. The use of insecticides as grain protectants should be explored. Also, alternative fumigants are needed. The 1991 Clean Air Act has reduced the use of methyl bromide, a

fumigant widely used in rice storage in the past (Cogburn 1985) that is now being phased out (Howell 2003). The registration of the fumigant sulfuryl fluoride, a methyl bromide replacement, is currently being evaluated and may be cancelled (EPA 2011), leaving phosphine as the only fumigant available. The repeated use of a single control agent will undoubtedly lead to resistance in insect pests of stored rice. Other forms of insect control should be evaluated. Heat and CO<sub>2</sub> treatments

are still uncommon (table 3) because of their high cost (Howell 2003). Similarly, infrared radiation is promising (Pan et al. 2008); however, the cost of implementation is still prohibitive. Research in these and other new forms of insect management is needed to make them cost effective.

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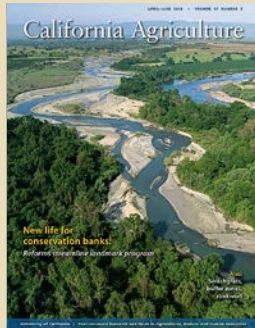
# 2013 index

The following peer-reviewed research articles, and news and editorial coverage, were published in *California Agriculture*, Volume 67, Numbers 1 to 4 (January–March, April–June, July–September, October–December), 2013. E = Article initially published online. Back issues are \$5 per copy, while supplies last. To subscribe to the journal, order back issues, search the archives or download PDFs of all research articles in full, go to:

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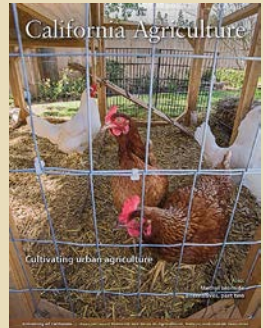
January–March, 67(1)



April–June, 67(2)



July–September, 67(3)



October–December, 67(4)

## Research and review articles

### Animal, avian, aquaculture and veterinary sciences

Hoar BR, Atwill ER, Carlton L, Celis J, Carabez J, Nguyen T. Buffers between grazing sheep and leafy crops augment food safety. 67(2):104–9.

Stinson S, Mete A. Popular Backyard Flock program reduces biosecurity risks of amateur production. 67(4):203–9.

SIDEBAR: Coats WJ. Hotline for sick birds. 67(4):208.

### Food and nutrition

Crawford PB, Schneider CL, Martin AC, Spezzano T, Algert S, Ganthavorn C, Nicholson Y, Neelon M, Wooten Swanson PC, Donohue S. Communitywide strategies key to preventing childhood obesity. 67(1):13–20. **HFC**

Crawford PB, Woodward-Lopez G, Gosliner W, Webb KL. Lessons of Fresh Start can guide schools seeking to boost student fruit consumption. 67(1):21–9. **HFC**

Scherr RE, Cox RJ, Feenstra G, Zidenberg-Cherr S. Integrating local agriculture into nutrition programs can benefit children's health. 67(1):30–7. **HFC**

### Human and community development

Campbell D, Trzesniewski K, Nathaniel KC, Enfield RP, Erbstein N. Positive youth development merits state investment. 67(1):38–46. **HFC**

Smith MH, Schmitt-McQuitty L. More effective professional development can help 4-H volunteers address need for youth scientific literacy. 67(1):47–53. **HFC**

Smith MH. Findings show lesson study can be an effective model for professional development of 4-H volunteers. 67(1):54–61. **HFC**

### Land, air and water sciences

Letey J, Vaughan P. Soil type, crop and irrigation technique affect nitrogen leaching to groundwater. 67(4):231–41. **E**

Mukome FND, Doane TA, Silva LCR, Parikh SJ, Horwath WR. Testing protocol ensures the authenticity of organic fertilizers. 67(4):210–6

Rosenstock TS, Liptzin D, Six J, Tomich TP. Nitrogen fertilizer use in California:

Assessing the data, trends and a way forward. 67(1):68–79. **E**

SIDEBAR: Editors. What is the California Nitrogen Assessment? 67(1):70.

SIDEBAR: White J. Background and scope of this article. 67(1):69.

SIDEBAR: White J. Glossary: Nitrogen in soils. 67(1):71.

Suddick EC, Ngugi MK, Paustian K, Six J. Monitoring soil carbon will prepare growers for a carbon trading system. 67(3):162–71.

### Natural resources

Bunn D, Lubell M, Johnson CK. Reforms could boost conservation banking by landowners. 67(2):86–95.

### Pest management

Ajwa H, Stanghellini MS, Gao S, Sullivan DA, Khan A, Ntow W, Qin R. Fumigant emission reductions with TIF warrant regulatory changes. 67(3):147–52. **MB**

Browne GT, Lampinen BD, Holtz BA, Doll DA, Upadhyaya SK, Schmidt LS, Bhat RG, Udumetaikul V, Coates RW, Hanson BD, Klonsky KM, Gao S, Wang D, Gillis M, Gerik JS, Johnson RS. Managing the almond and stone fruit replant disease complex with less soil fumigant. 67(3):128–38. **MB**

Brownsey R, Kyser GB, DiTomaso JM. Stinkwort is rapidly expanding its range in California. 67(2):110–5.

Fennimore SA, Serohijos R, Samtani JB, Ajwa HA, Subbarao KV, Martin FN, Daugovish O, Legard D, Browne GT, Muramoto J, Shennan C, Klonsky K. TIF film, substrates and nonfumigant soil disinfestation maintain fruit yields. 67(3):139–46. **MB**

Gao S, Hanson BD, Qin R, Cabrera J, Gerik JS, Wang D, Browne GT. Totally impermeable film (TIF) reduces emissions in perennial crop fumigation. 67(4):217–21. **MB**

Hanson BD, Gao S, Gerik J, Qin R, Cabrera JA, Jhala AJ, Abit MJM, Cox D, Correia B, Wang D, Browne GT. Preplant 1,3-D treatments test well for perennial crop nurseries, but challenges remain. 67(3):181–9. **E**, **MB**

Lewis VR, Moore SE, Tabuchi RL, Sutherland AM, Choe D-H, Tsutsui ND. Researchers combat resurgence of bed bug in

behavioral studies and monitor trials. 67(3):172–8.

SIDEBAR: White J. Closer look: What if I suspect a bed bug infestation? 67(3):177.

Udumetaikul V, Coates RW, Upadhyaya SK, Browne GT, Shafii M, Gillis M. Tractor-mounted, GPS-based spot fumigation system manages Prunus replant disease. 67(4):222–7. **MB**

## News departments

### Corrections

Ajwa H, Stanghellini MS, Gao S, Sullivan DA, Khan A, Ntow W, Qin R. Fumigant emission reductions with TIF warrant regulatory changes. 67(4):195.

Hoar BR, Atwill ER, Carlton L, Celis J, Carabez J, Nguyen T. Buffers between grazing sheep and leafy crops augment food safety. 67(3):119.

### Editorials/editorial overviews

Allen-Diaz B. How will we feed 8 billion people in 2025? Public investment in UC fosters answers for global food system. 67(2):82.

Eastin D. UC addresses needs of California youth. 67(1):3–4. **HFC**

Pérez JA. Urban agriculture is a gateway to healthy foods. 67(4):192.

Surls RA, Hayden-Smith R. UC Cooperative Extension's collaborations grow with the centuries. 67(3):118.

### Index 2012

67(1):63.

### Letters

67(2):85.

### Other news

Allen-Diaz B. 2013 Statewide conference UC ANR: California roots, global reach. 67(1):5.

Editors. California Agriculture staffing changes. 67(4):195.

White J. Methyl bromide primer and timeline. 67(3):121. **MB**

Weiland JE, Littke WR, Haase DL. Forest nurseries face critical choices with the loss of methyl bromide fumigation. 67(3):153–61. **MB**

### Plant sciences

DiTomaso JM, Barney JN, Mann JJ, Kyser G. For switchgrass cultivated as biofuel in California, invasiveness limited by several steps. 67(2):96–103.

White J. Methyl bromide terminology. 67(3):122. **MB**

### Outlook

Browne GT. Specialty crops and methyl bromide alternatives: Taking stock after 7 years. 67(3):123–4. **MB**

Martin P. Immigration reform and California agriculture. 67(4):196–8.

### Research news

Meadows R. Initiative promotes youth development, healthy living, science literacy. 67(1):9–12. **HFC**

Meadows R. Researchers develop alternatives to methyl bromide fumigation. 67(3):125–7. **MB**

Meadows R. UC Cooperative Extension helps farming sprout in the city. 67(4):199–202.

SIDEBAR: Meadows R. A snapshot of urban agriculture in Los Angeles. 67(4):202.

White J. California enacts law to strengthen conservation bank program. 67(2):85.

White J. Early findings: Food insecurity, obesity high in low-income Latino families. 67(1):7–8. **HFC**

### Special issue/section key

**HFC** = Healthy families and communities

**MB** = Methyl bromide alternatives

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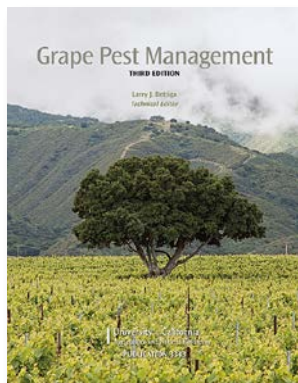
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