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 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.

Submissions. California Agriculture manages the peer review of manuscripts online. Please read our Writing Guidelines before submitting an article; go to: http://californiaagriculture.ucanr.edu/submit.cfm.

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100 Years of Science and Service

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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.

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...
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.

Contributions to California. In these pages, you can read how a Fresno County CE advisor helped alfalfa seed growers stave off infestations of Africanized bees and increase crop yields.

In another example of the value of partnerships, you can learn how an advisor, a grower, an agriculture commissioner and a retired army officer teamed up to create a popular tourist destination and apple-growing region in a Northern California community whose orchard livelihood once faced extinction.

These are just two examples of how UCCE has come through in a crisis. Every day, its researchers and advisors apply scientific innovations to the challenges of increasing yields, battling invasive pests and diseases, reducing energy use, conserving water, breeding new crop varieties and developing sustainable farming methods.

Over the years, the Cooperative Extension mission has evolved with the times, and it will keep evolving. For example, during World Wars I and II, UCCE helped Californians plant victory gardens to increase the wartime supply of fresh produce. Today, UCCE runs Master Gardener programs in 45 counties, teaching people to enrich their homes and communities with sustainable, edible and ornamental gardens.

California 4-H still provides young people with the opportunities to raise livestock and compete at county fairs. Now, its programs have expanded to include technical knowledge with robot-building competitions and computer training classes.

Particularly noteworthy is the role UCCE and ANR play in building healthier communities. Through nutrition programs in underserved rural and urban neighborhoods, UCCE is fighting obesity, diabetes, high blood pressure and other chronic conditions related to diet. These efforts benefit all Californians by helping curb rising health care costs.

Critical responses

With every crisis California faces, UCCE comes through with practical, on-the-ground solutions. With our state now facing a drought, ANR is committed to using its expertise to help our agriculture industry survive. We all know California is no stranger to the cycles of dry years and water rationing. ANR advances in irrigation, plant breeding and conservation methods helped our state survive droughts of the past. And we can do it again.

Climate change is the latest challenge in the water shortage difficulties facing our state. The effects of a warming environment on California’s fields, forests and wildlife has risen to the top of the University’s research concerns. While UC scientists study the causes and effects of climate change, UCCE will be applying that knowledge to technological innovations that will supply California with the latest drought survival strategies.

Advocating

A few months ago, I met with the President’s Advisory Commission on Agriculture and Natural Resources for the first time, and I’m looking forward to meeting with that group again in April. I plan to work closely with its members to ensure that ANR has the tools to meet the needs of California.

When I was appointed UC’s 20th president, I pledged to be the best advocate possible for the University of California. I am eager to be a partner with — and advocate for — ANR and all its valuable programs. In essence, that means I will be an advocate for California agriculture.

I’ll be looking for opportunities to talk about all the ways the ANR family makes life better for California families. Don’t be surprised if I call on you to help spread the word.

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Smith-Lever Act of 1914: An Act to provide for cooperative agricultural extension work between the agricultural colleges in the several States receiving the benefits of an act of Congress approved July second, eighteen hundred and sixty-two, and of acts supplementary thereto, and the United States Department of Agriculture.
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.
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

**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

**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

**Loretta Smith**  
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

On 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

1862
President Lincoln signs Morrill Act, authorizing development of agricultural “land-grant” colleges in each state

1868
University of California founded to teach “agriculture, mining and the mechanical arts”

1869
Congress passes the Morrill Act, providing federal funding for education in agriculture

1876
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1877
Andrew Hansen Christiansen named California’s first Extension farm advisor, placed in Humboldt County

1879
UC agricultural clubs formed in Ferndale and Fortuna; these early clubs evolved into today’s 4-H program

1880

1887
Hatch Act establishes federal funding for agricultural research in state land-grant colleges

1890
UC Agricultural Extension Service (later renamed “Cooperative Extension”) appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

1894
Congress passes the Smith-Lever Act of 1914: An Act to provide for cooperative agricultural extension work between the agricultural colleges in the several States receiving the benefits of an act of congress approved July second, eighteen hundred and sixty-two, and of acts supplementary thereto, and the United States Department of Agriculture.

1896
B.H. Crocheron recruited to direct state’s Agricultural Extension Service, which he does for next 35 years

1897
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1898
UC Agricultural Extension Service appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

1900

1901
California Agricultural Extension Service (later renamed “Cooperative Extension”) appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

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

1910
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1911
UC Agricultural Extension Service (later renamed “Cooperative Extension”) appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

1912
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1913
Andrew Hansen Christiansen named California’s first Extension farm advisor, placed in Humboldt County

1914
Congress passes the Smith-Lever Act, making federal funds available for extension work

1915
UC Agricultural Extension Service (later renamed “Cooperative Extension”) appoints farm advisors in Glenn, Solano, Stanislaus and Placer counties

1916
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1917
Emergency war appropriations provide growth for UC Agricultural Extension as “food for victory” becomes national priority

1918
First UC Extension specialist, a poultryman, hired with goal to double egg production from 80 eggs per hen per year average

1919
B.H. Crocheron recruited to direct state’s Agricultural Extension Service, which he does for next 35 years

1920

Continued on page 10
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.

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

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

1922

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

1923

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

1924

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

1925

Hilgardia, a monographic series of agricultural science, begins

1926

First Agricultural Extension circulars published

1927

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

1928

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

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

1920

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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
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 wartime 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.

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.”

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

1955
Extension staff totals 549, more than double 1940’s Extension workers

1956
UC Davis scientists and Extension farm advisors develop tomato varieties around state, identifying three new hybrids with superior yields

1957
Extension farm advisors work on improving irrigation efficiency by applying water based on specific soils and crop needs

1959
Extension agricultural economists study challenges and opportunities in California’s rural-urban transition
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.

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

1961
- UC’s pioneering biocontrol efforts well under way; scientists release imported parasitic wasps to combat specific citrus pests

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

1963
- Farm advisors work with rice growers in Butte, Colusa, Glenn, San Joaquin, Sacramento, Sutter, Yolo and Yuba counties on fertilizer efficiency

1964
- 50th anniversary of Smith-Lever Act; UC Extension has 352 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

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

1967
- Extension farm advisors work with UCD’s Department of Vegetable Crops to develop new varieties of peppers resistant to tobacco mosaic virus

1968
- UC conducts drip irrigation experiments on San Diego County avocados

1969
- Expanded Food and Nutrition Education Program (EFNEP) developed to reach low-income families

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

1972
- UC works with Santa Clara County’s canning industry on using cannery wastes as soil amendment

1973
- In response to environmental concerns, UC works with 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 provided.

1974
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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
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...
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


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.

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

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

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

Farming 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

Most 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 and...
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 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
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% of the total (CDFA 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 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.

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

TABLE 1. Details of wine grape production, by region, 2010
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 (CDF 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 re-vegetation 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 (CDF 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
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

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**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 CDFA 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

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**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 and some $8 million was carried forward from the previous year, sourced and allocated as shown in figure 4. 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 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

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**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 PD-related programs and expenditures, 2009–2010]
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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.
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

<p>| TABLE 3. Expected cost of vine losses, by grape type and region, 2010 |
|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Type and region</th>
<th>Bearing area</th>
<th>Low PD pressure</th>
<th>High PD pressure</th>
<th>Most likely PD pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wine grapes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Napa-Sonoma (Districts 3, 4)</td>
<td>100.4</td>
<td>13.0</td>
<td>93.1</td>
<td>33.5</td>
</tr>
<tr>
<td>Coastal (Districts 1, 2, 5, 6, 7, 8)</td>
<td>124.8</td>
<td>0.0</td>
<td>29.2</td>
<td>6.5</td>
</tr>
<tr>
<td>San Joaquin Valley north (Districts 11, 17)</td>
<td>84.5</td>
<td>0.0</td>
<td>4.3</td>
<td>2.1</td>
</tr>
<tr>
<td>San Joaquin Valley south (Districts 12, 13, 14, 15)</td>
<td>132.9</td>
<td>0.0</td>
<td>13.7</td>
<td>4.7</td>
</tr>
<tr>
<td>Southern California (District 16)</td>
<td>1.0</td>
<td>0.2</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Northern California (Districts 9, 10)</td>
<td>13.3</td>
<td>0.0</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Total wine grapes</td>
<td>456.9</td>
<td>13.2</td>
<td>143.0</td>
<td>47.7</td>
</tr>
<tr>
<td>Raisin grapes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Joaquin Valley south (Districts 12, 13, 14, 15)</td>
<td>200.2</td>
<td>0.0</td>
<td>7.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Southern California (District 16)</td>
<td>1.1</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Total raisin grapes</td>
<td>201.4</td>
<td>0.1</td>
<td>7.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Table grapes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Joaquin Valley (Districts 12, 13, 14, 15)</td>
<td>71.5</td>
<td>0.0</td>
<td>10.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Southern California (District 16)</td>
<td>7.0</td>
<td>0.9</td>
<td>4.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Total table grapes</td>
<td>78.5</td>
<td>0.9</td>
<td>14.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Total grapes</td>
<td>736.8</td>
<td>14.2</td>
<td>165.0</td>
<td>56.1</td>
</tr>
</tbody>
</table>

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

Table 4 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

<p>| TABLE 4. District 4 sample calculation of costs of vine loss, 2010 |
|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Years after vine death</th>
<th>Establishment cost*</th>
<th>New vine planted in year 1</th>
<th>Mature vine</th>
<th>Net loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$/vine</td>
<td>tons/acre</td>
<td>$/acre</td>
<td>$/acre</td>
</tr>
<tr>
<td>0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>13.81</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1.50</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.00</td>
<td>1.0</td>
<td>3,384</td>
<td>−148</td>
</tr>
<tr>
<td>4</td>
<td>0.00</td>
<td>3.0†</td>
<td>5,199</td>
<td>4,511</td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
<td>5.0</td>
<td>5,582</td>
<td>10,600</td>
</tr>
<tr>
<td>Total loss</td>
<td>43.19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
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.

The total cost is comprised of $48.3 million in funded activities undertaken by 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 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.

References


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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 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 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).
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...
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.”

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 cookery, 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.
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:

\[
P(c) = \frac{c!}{n!} \times 100\%
\]

If \( n \) = number of choices and \( c \) = number correct, then

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 diabetic patients 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**

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

* 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% \((P = 0.4930)\). 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 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.
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

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

n = 506: All participants combined.

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 state-wide 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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**References**


http://californiaagriculture.ucanr.edu • JANUARY–JUNE 2014 37
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% 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. Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v068n01p38&fulltext=yes doi: 10.3733/ca.v068n01p38

Randall Mutters
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*

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

* 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 = 29) 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

<table>
<thead>
<tr>
<th>Structure type</th>
<th>On-farm operations (n = 32)</th>
<th>Off-farm operations (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Total capacity</td>
</tr>
<tr>
<td>Round metal bins</td>
<td>10</td>
<td>64,105</td>
</tr>
<tr>
<td>Concrete silos</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flat warehouses</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
```
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...
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 reporting 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 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. 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.
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

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**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.”

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

<table>
<thead>
<tr>
<th>Action</th>
<th>On-farm operations (<em>n</em> = 31)</th>
<th>Off-farm operations (<em>n</em> = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerate grain</td>
<td>22.6</td>
<td>37.9</td>
</tr>
<tr>
<td>Spray surface of grain mass</td>
<td>3.2</td>
<td>0.0</td>
</tr>
<tr>
<td>Spray area around storage</td>
<td>9.7</td>
<td>20.7</td>
</tr>
<tr>
<td>Fumigate grain</td>
<td>90.3</td>
<td>96.6</td>
</tr>
<tr>
<td>CO₂ treatment</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Heat treatment</td>
<td>0.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Other</td>
<td>12.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>
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.

| 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 (α = 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). 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%.

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 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
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 CO₂ 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.

References


L.A. Espino is UC Cooperative Extension Rice Farming Systems Advisor, Colusa, Glenn and Yolo Counties; C.A. Greer is UC Cooperative Extension Rice Farming Systems Advisor, Sutter-Yuba, Sacramento and Placer-Nevada Counties; R.G. Mutters is UC Cooperative Extension Farm Advisor, Butte County; and J.F. Thompson is Emeritus Specialist, Department of Biological and Agricultural Engineering, UC Davis. This research was funded by the Western IPM Center 2011 Competitive Grants Program. We thank the California Warehouse Association and county agricultural departments for suggesting contacts, reviewers of the draft questionnaire for their suggestions and survey respondents for their answers and comments.
Research and review articles

Animal, avian, aquaculture and veterinary sciences


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

Food and nutrition


Scherer 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

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
Lety J, Vaughn P. Soil type, crop and irrigation technique affect nitrogen leaching to groundwater. 67(1):231–41. E

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


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


Natural resources

Pest management


News departments
Corrections


Editorials/editorial overviews
Allen-Diaz B. How will we feed 8 billion people in 2057? 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


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

Weiland JE, Little WR, Haase DL. Forest nurseries face critical choices with the loss of methyl bromide fumigation. 67(3):133–61. 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.

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