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California Agriculture

Better wines, more vines:
California and the world wine revolution

University of California | Peer-reviewed Research and News in Agricultural, Natural and Human Resources

UC know-how can boost California wine economy

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IN California, grape cultivation and its value-added agricultural product, wine, are major factors in the state's economy. California wine is valued at $16.6 billion retail (see page 12), and total economic activity from the wine industry is estimated at over $45 billion. This economic activity has now reached a critical juncture when it is time to evaluate our research investment.

The United States will soon be the largest global wine market. Total consumption has increased by 40% over the last 10 years, and per capita consumption has grown 23%. However, with per capita consumption at about 2.4 gallons there should be room for additional growth, since most other Western countries consume more. For instance, per capita wine consumption is 5 gallons per year in the United Kingdom and 6.5 gallons in Australia.

With such significant growth potential, U.S. producers are being challenged by wine imports for market share. U.S. wine drinkers have been consuming more imported wine, with imports growing to 27% of the market in 2005, doubling since 1990. The largest growth in the import market is due to a phenomenal explosion in the importation of Australian wine, which rose by 1500% over the last 10 years. Australia is poised to become our number one import country in 2007.

The tremendous success of the Australian wine industry is based on a visionary investment partnership between the Australian industry, government and academia. This comprehensive effort includes new and updated vineyard plantings, new production facilities, major marketing campaigns, investments in the education of skilled professionals, and scientific research targeted at matching the qualities of Australian wine to market preferences at affordable prices.

To maintain a competitive and sustainable business position, the U.S. grape and wine industry must strategically invest in the future in these same areas. There have been significant investments in new plantings, for instance in the Central Coast region (see page 11), and some new facilities are being built in those areas to accommodate production. But the investments in education and research have not been comparable to other major wine-producing countries. To address this, there have been calls for increased research funding through various means, and concern has been expressed over the shortage of trained viticulture and enology professionals. Clearly, more can be done in these latter areas.

The recent growth in new winery businesses has far exceeded the capacity of existing educational programs; the situation has become serious enough to stimulate a session on the workforce at the nationwide Unified Wine and Grape Symposium in 2006. Due to a shortage of locally trained individuals, many new hires are from overseas or lack training in viticulture or enology. To address this, we need hard data on market demand, and then we must create a plan to educate the skilled workforce necessary to keep the California wine industry competitive.

Research in California has been funded at lower levels than that of overseas competitors for many years, particularly in contrast to Australia. For the 2007–2008 cycle, for example, less than $1 million in competitive funds went to California public institutions for enology research, while the Australian Grape and Wine Research and Development Corporation reported an expenditure of $20.7 million, including market analysis.

With its strong historical record in education, research, extension and ongoing education, the University of California can help address these areas of need. A recent study of wine and grape research showed that the United States (largely UC) has a dominant but threatened position, with Australian research output rapidly growing. U.S. research is also recognized as authoritative to others in the field, as it has a very high citation rate. This is a strong research foundation on which to build in the future.

Graduates from UC Davis in the fields of enology and viticulture have been dominant players in the profession for more than 50 years. Graduates are in high demand by vineyard and wine businesses in California, and the wines they produce regularly receive state and national awards. The education delivered offers scientific depth — with an emphasis on critical thinking, problem-solving and life-long learning — and is essential to addressing competitive challenges to California grape and wine businesses. And, Ph.D. graduates become the faculty at other wine and grape programs across the United States, a necessary stimulus to the expansion of a wine culture nationwide. It is important to note that the output of research-trained viticulture and/or enology graduates, M.S. winemakers and Ph.D. graduates, is constrained by the availability of funded grape and wine research projects.

Investments in education and research are essential to maintain the vitality of the industry. UC can help plan and build a bold future with research on sustainable practices and a new understanding of wine flavor, giving California winegrowers an edge in the market. We stand ready to help the industry strengthen a competitive, capable and flexible workforce, and develop the future educators necessary to sustain this momentum.

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Cover: California's $45 billion wine industry continues to grow and change (see p. 12). In Sonoma County's Alexander Valley (shown), vineyards continue to expand, as do premium wine-growing areas along the coast (see p. 11). *Photo: ©2008 Herb Lingl/aerialarchives.com.*

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Research and review articles

About California Agriculture

California Agriculture is a quarterly, peer-reviewed journal reporting research, reviews and news from the Division of Agriculture and Natural Resources (ANR) of the University of California. The first issue was published in December 1946, making it one of the oldest, continuously published, land-grant university research journals in the country. The circulation is currently about 15,000 domestic and 1,800 international.

Mission and audience. *California Agriculture*'s mission is to publish scientifically sound research in a form that is accessible to a well-educated audience. In the last readership survey, 33% worked in agriculture, 31% were faculty members at universities or research scientists, and 19% worked in government agencies or were elected office holders.

Current indexing. *California Agriculture* is indexed in the Commonwealth Agricultural Bureau databases, Proquest, AGRICOLA and Google Scholar. In addition, all peer-reviewed articles are posted at the California Digital Library's eScholarship Repository.

Authors. Authors are primarily but not exclusively from UC's ANR; in 2005 and 2006, 14% and 34% (respectively) were based at other UC campuses, or other universities and research institutions.

Reviewers. In 2005 and 2006, 13% and 21% (respectively) of reviewers came from universities and research institutions or agencies outside ANR.

Rejection rate. Our rejection rate is currently 26%. In addition, in two recent years the Associate Editors sent back 11% and 26% for complete resubmission 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 a third reviewer. The reviewers and Associate Editors almost always require revision before acceptance. 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 audience of lay readers and multidisciplinary academics.

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WHAT DO YOU THINK?

The editorial staff of *California Agriculture* welcomes your letters, comments and suggestions. Please write to us at 6701 San Pablo Ave., 2nd floor, Oakland, CA 94608 or calag@ucop.edu. Include your full name and address. Letters may be edited for space and clarity.

Ag info network needs funds

The topic of water research, as reported in *California Agriculture* (October-December 2007), points out a persistent theme of land-grant university scientists: Once initial studies of a subject have been undertaken, there is a need for extended research, including fieldwork, to solve important questions. For instance, harmless *E. coli* is used as an indicator of pathogens in water supplies — but the critical questions concerning the load and concentration of actual pathogens in water bodies, and their response to management practices and wetlands, are unanswered (page 159). A separate article on juniper removal also refers to "substantial data and research gaps in our knowledge" of the influence of western juniper on hydrology (page 166).

The resolution of such issues as the long-term health of our citizens and the continuation of problems in the environment depends on well-integrated agricultural and environmental research. However, federal support for such research has been steadily decreasing, at the same time that funding for health research, development and dissemination has increased exponentially.

It is critical for scientists, educators, extension agents and agribusiness leaders to build a coherent and responsive system serving all communities. They need resources for research in the public interest, and that research must be available. Increasingly that means "discoverable" on the Internet.

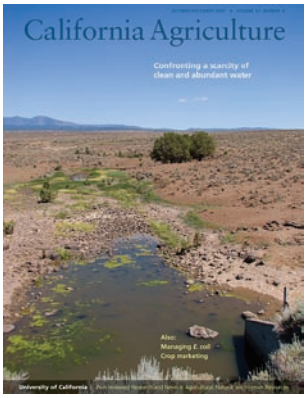
The National Agricultural Library, land-grant universities and related organizations are designing a digital library that will support dynamic, collaborative and fully integrated electronic agricultural information systems. However, planning for the Digital Library for Agriculture has been hampered due to the lack of funds, which have basically been static since 1985.

USAIN, the United States Agricultural Information Network, (representing 40 states and five countries) has recently advocated for adequate funding through the Farm Bill, which is still pending approval in Congress (www.usain.org).

Norma Kobzina, President, USAIN 2007-2008
Head, Information Services
UC Berkeley Bioscience and Natural Resources Library

Cause of Klamath fish die-offs disputed

An incorrect statement was made concerning the cause of fish die-offs (attributed to Levy [2003]) in the juniper removal article in *California Agriculture* (October-December 2007). The National Research Council (NRC) is the operating arm of the



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National Academy of Sciences (NAS) and the National Academy of Engineering (NAE). An NRC committee spent almost 2 years reviewing agency decisions surrounding the Klamath water situation (see *Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery*, National Academies Press, 2004). William Lewis of the University of Colorado testified before the U.S. House of Representatives Subcommittee on Water and Power on July 31, 2007. Excerpts of his testimony follow:

"Between 2002 and 2004, I was chair of the Committee on Endangered and Threatened Fishes in the Klamath River Basin. An important question considered by the committee . . . is whether management of water by the Klamath Project was responsible for withholding the pulse of flow that would have allowed the salmon to migrate. The NRC committee concluded that this is very unlikely. The Klamath Project is located over 150 miles upstream from the mouth, and water flowing through the Klamath Project accounts for only 10% of the total flow at the mouth; large tributaries entering the river below the Klamath Project contribute most of the flow at the mouth. Furthermore, the Klamath Project releases water that is warm because it comes from storage lakes rather than reaching the stream through groundwater or surface runoff. The committee concluded that a relatively small amount of warm water propagated over a distance of 150 miles would not have made a critical difference to the salmon that were staging for migration at the mouth of the river."

Michael Byrne
Klamath Falls, Ore.

Cal Ag research helps improve water quality

Editor's note: California's Proposition 50 was passed in 2002 with $3.44 billion in bond funding for water quality improvements.

We had between 65 and 70 people at our Prop 50 Upper Feather River Watershed Irrigated Lands Stakeholder Meeting in Quincy on Nov. 15, 2007. Members of the Prop 50 Project Team along with

Letters

representatives from state and regional agencies gave presentations and participated in discussions.

In addition to results of season-long water-quality monitoring from across the watershed, most participants received a copy of the October-December 2007 *California Agriculture* with the excellent article by Knox et al., "Management reduces *E. coli* in irrigated pasture runoff."

Co-author Ken Tate, a member of the Project Team, discussed management practices that local agricultural owners who irrigate for forage and livestock could implement on their ranches, based upon work conducted at the UC Sierra Foothill Research and Extension Center and summarized in *California Agriculture*. Based on the article and Ken's comments, members of the Upper Feather River Watershed Group felt that greater efforts could be undertaken to reduce *E. coli* levels in local streams by having tailwater go through grassed waterways or mini-wetlands before returning to the main channel. Ranchers also felt that they could improve their grazing practices to minimize the time cattle are in actively irrigated fields. We will continue to monitor *E. coli* levels on behalf of ranchers next year and hopefully see some improvements.

Holly George
Livestock and Natural Resources Advisor
UC Cooperative Extension, Plumas-Sierra counties

To our readers

Andrea Laue

Laue leads *Cal Ag* into digital future

Andrea Laue joined *California Agriculture* journal as Web Editor on Aug. 1, 2007. Laue is leading a new digital publishing initiative to digitize copies of the journal dating back to 1946, and to redesign the information architecture of the journal's Web site. She will also work on increasing the journal's exposure in research databases and popular search engines such as Google. "*California Agriculture* content should be more findable, retrievable and usable online very soon," Laue says. In concert with *California Agriculture* and Communication Services staff, Laue is implementing a comprehensive proposal that integrates the ideas and skill sets of collaborating staff.

Laue earned her Ph.D. in English and Digital Humanities from the University of Virginia in 2006. She has worked on several scholarly digital publishing projects, including the Mark Twain Project Online at UC Berkeley. Laue can be reached at (510) 642-2431, ext. 16, or andrea.laue@ucop.edu.

Outreach news

Service grants allow 4H-ers to build healthier communities

ON the morning of a school holiday in mid-November, 12-year-old Sean Boerger got a ride across town and presented his ideas for installing benches in a wetland to officials of the Siskiyou Land Trust. Boerger is junior leader of the Strawberry Valley 4-H woodworking group, and he knows about making and installing public benches. Last year, his group won a 4-H service-learning grant to provide benches at Siskiyou Lake. This year, a new grant of $1,100 will allow the group to make benches for the Sisson Meadow Wetlands, which the land trust has recently restored in downtown Mt. Shasta.

"I think it's going to be fun for the group," Boerger says. "The benches will give people a place to sit and make the area look nicer, and we get to learn more woodworking skills."

That's exactly the concept of service learning — serving the community and, in the process, gaining educational opportunities. Last year, the community of Lake Siskiyou received beautiful, sturdily built benches, and Boerger and his group learned many things, including how a cedar snag is felled and turned into lumber at the town mill. On the new project, Boerger is looking forward to the trickiest aspect: "I'm not quite sure how we're going to do the foundation, because it's kind of swampy out there," he says.

The service-learning grants are part of the California 4-H Youth Development Program sponsored by the University of California Division of Agriculture and Natural Resources (the 4 H's stand for "Head, Heart, Hands and Health," and members pledge their hands to "larger service").

"The goal," says Pat English, California 4-H program representative, "is to expand members' skills in citizenship, leadership and life."

Strawberry Valley 4-H Club

With support from a 4-H service-learning grant, the Strawberry Valley 4-H woodworking group built and installed benches at Siskiyou Lake.

Citizenship has three definitions: who or what we are, what we believe, and what we do, English explains: "The service-learning projects provide teachable moments, opportunities for reflection and the means to gain experience in community building.'"

This is the fifth year California 4-H service-learning grants have been awarded; distributions have ranged from $5,500 to $14,900 per year and are a gift from the Thomas and Dorothy Leavey Foundation. Proposed projects must contain aspects of community service and education; address significant environmental, economic and/or social issues affecting California's youth, families and communities; and involve collaboration with other community-based organizations.

Grants for four other service-learning projects were awarded in 2007. Another Siskiyou County 4-H group received $1,000 to organize a "senior prom" for elderly residents. In Sacramento County, a 4-H club has $2,000 to provide environmental education and outdoor living experience to 1,000 elementary students from economically disadvantaged neighborhoods. In San Mateo County, members of the Belmont 4–H Clothing Project were awarded $233 to create dyed-silk scarves for a local hospital. Also, $500 of seed money was awarded for surely the most ambitious youth service-learning idea ever, the 4-H Million Trees project.

The Pacifica 4–H club is developing plans to plant a million trees across the United States to combat global warming; their estimated budget for the project is $1 million. High-school freshman Laura Webber saw Al Gore's *An Inconvenient Truth* with her father last winter and was galvanized to do something; she and the other club members worked out the details.

Although the Pacifica group will plant some trees, the aim of the project is to enlist the help of the 90,000 other 4-H clubs in the country, a total of 7 million youth. Each club has to plant only 12 trees to achieve the goal (www.4hmilliontrees.org).

Engaging in public projects that serve the community, or the whole world, in tangible, recognizable and important ways motivates young people (see page 40). The projects inspire their adult leaders also. Todd Ellorin, the Siskiyou Woodworking project leader says, "These kids want to know where the lumber is coming from and how the project affects the environment. I really learn from them."

The Siskiyou Land Trust listened to Boerger's new bench ideas "and made some changes," Boerger says. Ellorin says he will discuss with the group a way to respect the client's wishes and also try something new. That's another skill that's definitely useful for the adult world. — *Hazel White*


Jose Luis Villegas/UC Davis

Oiled birds cleaned up and sent home; research studies launched

▲ **After the November 2007 oil spill in the San Francisco Bay, staff and volunteers with the Oiled Wildlife Care Network washed about 800 oiled birds at their Cordelia facility.**

The 58,000-gallon oil spill in San Francisco Bay on Nov. 7, 2007, was the worst in a decade, and weeks later rescuers were still collecting coated birds from beaches. The oiled birds — primarily grebes, scaups and surf scoters — were brought to the Cordelia facility of the Oiled Wildlife Care Network, which comprises 25 organizations and a dozen facilities from Crescent City to San Diego, and is directed by UC Davis wildlife veterinarian Michael Ziccardi.

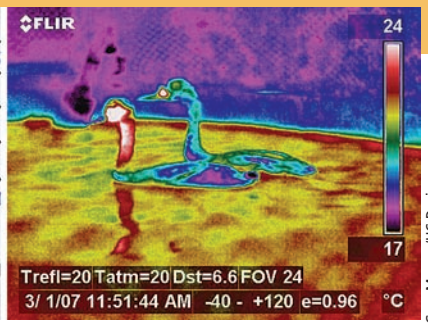
Saving oiled birds is far from a sure thing. "They arrive cold and weak because oil coats their feathers, forcing them to come out of the water to survive," Ziccardi says. Many die before they can even be cleaned, and more die in the rehabilitation pools prior to release. By the end of November, more than a thousand birds had been collected, nearly 800 had been washed, and more than 340 had been rehabilitated and released in Tomales and Half Moon bays, which lie beyond the reach of the oil spill. Nearly 1,750 birds were collected dead, and about 600 died or were euthanized in captivity.

The Cordelia center — called the San Francisco Bay Oiled Wildlife Care and Education Center — is a 12,000-square-foot, $2.7 million facility capable of caring for between 1,000 and 1,500 sick birds, and is co-managed by the International Bird Rescue Center. The Oiled Wildlife Care Network is funded by the California Department of Fish and Game, with interest on the $50 million California Oil Spill Response Trust Fund built from assessments on the oil industry.

Studies aimed at survival of oiled birds

Little is known about what happens to the relatively few birds lucky enough to make it back to the wild, but Ziccardi and his colleagues are trying to find out. The veterinarians are implanting about 25 oiled and rehabilitated birds and an equal number of

Jose Luis Villegas/UC Davis



Greg Massey/UC Davis

***Above left*, an oiled bird. *Above right*, UC Davis researchers will test the use of infrared thermography to take the temperature of oiled birds. Bird on right is cold (blue neck and head); bird on left is warm (red neck).**

control birds with tiny backpack-style radio transmitters so their whereabouts and survival can be tracked.

The team is also launching several new studies aimed at increasing the survival of oiled birds. These include using infrared thermography to determine whether cleaned birds are still losing body heat, and identifying the causes of anemia, which is common in birds that ingest oil. A related project will determine whether various blood tests can predict survival. "The oiled birds' blood will be analyzed for hemoglobin, which might be a better indicator for anemia in dehydrated birds, as well as fibrinogen, a protein indicative of inflammation," Ziccardi explains.

To better protect the birds' health, tests will be conducted on the air, water, hard surfaces and feeding tubes in the rescue center for a mold called Aspergillus. To better protect the rescue workers' health, tests will be done for the presence of zoonotics — disease-causing organisms that can travel from animals to humans — such as Salmonella and Campylobacter.

The studies will be led by Ziccardi and UC Davis spill response veterinarian Greg Massey. The research teams will include veterinary and postgraduate students at the UC Davis School of Veterinary Medicine, as well as scientists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, California Department of Fish and Game's Office of Oil Spill Prevention and Response (OSPR), and Humboldt State University.

"We want to take advantage of this tragic spill to gather as much information as possible so that we can improve our effectiveness and save more birds in the future," Ziccardi says.

— Robin Meadows and Editors

FOR MORE INFORMATION

International Bird Rescue Research Center:
http://ibrrc.org/index.html

Oiled Wildlife Care Network:
www.vetmed.ucdavis.edu/owcn

UC Cooperative Extension helps people cope with Southern California wildfires

The wildfires that devastated Southern California in October 2007 came only 4 short years after the region's previous catastrophic burn, which was in October 2003. These two firestorms had many similarities, with both being fanned by hot, dry Santa Ana winds, and both ultimately burning hundreds of thousands of acres. But there was also a key difference: UC Cooperative Extension made it easier for people to cope with wildfire the second time around.

"After the 2003 fires, we realized that we didn't have a way to help people during and after a fire," says Terry Salmon, director of San Diego County Cooperative Extension. "There was lots of information but it wasn't centralized."

Wildfire Web site

To fix this problem, Salmon and his colleagues developed a comprehensive wildfire Web site called the Wildfire Zone. The site has three main sections explaining what to do before, during and after a fire, and was adapted from a University of Nevada Cooperative Extension Web site. The project was in collaboration with the County of San Diego, and received funding from the County as well as the Federal Emergency Management Agency.

Fortuitously, the Wildfire Zone was finished just in time for the 2007 fires. "It hadn't even been advertised, and it got 300,000 hits the day after the first fire," says Salmon, adding that the Web site was also useful to the county Office of Emergency Services. San Diego got the worst of the fires, which burned 380,000 acres there in a week, forcing the evacuation of half a million people and destroying well over a thousand homes.

People accessing the new Web site got immediate practical information. For example, before evacuating, they should help firefighters by filling garbage cans with water, propping a ladder against the roof, and turning on all the lights to make the house easier to find in the smoke. In addition, people could enter their ZIP code to find out which emergency number to call. "It's confusing because there are so many fire departments in the county," Salmon says.

Fire-safe homes

The Wildfire Zone's initial focus was on how to prepare for fires. "You can do a lot to protect your house from a wildfire," says Stephen Quarles, a wood durability advisor at Contra Costa County Cooperative Extension. The Web site has step-by-step advice on retrofitting houses to reduce their

fire risk, from using noncombustible building materials such as concrete roof tiles to establishing 100 feet of "defensible space" around homes to hinder the spread of fire. Ways to create defensible space include landscaping with fire-resistant plants, irrigating regularly and using rocks instead of wood mulch right next to a house.

The Web site also has links to demonstration fire-safe gardens, and plans are under way for demonstration retrofitted buildings. "We don't want to just tell people what to do, we want to show them," Salmon says. For example, many houses burn because a wood fence catches on fire. This can be avoided by adopting the current code for new buildings, which stipulates that wood fences can't touch a house.

New building codes

Now, the Wildfire Zone's post-fire section is being expanded. One important update for people who lost their homes is that there is a new state building code for the wildland-urban interface, where the risk of fire is most severe. While current law requires that materials be fire-resistant, the new law will go even further and require that materials be ignition-resistant.

The goal is to protect buildings from embers, which can fly up to a mile from a wildfire. "Vents offer an easy entry point for burning embers," Quarles says. "Embers that slip through attic vents can ignite debris and items stored there, and subsequently construction materials, setting the home ablaze from within." The new building codes are effective Jan. 1, 2008, in areas under state jurisdiction, and July 1, 2008, in areas under local jurisdiction.

More outreach

Because fire is a fact of life throughout the Western states, UC Cooperative Extension organized a regional workshop for wildfire specialists to pool their resources. The first Western Region Cooperative Extension Wildfire Workshop was held in June 2007 in San Diego, and the second is planned for 2008 in Lake Tahoe.

To help get information to more people in San Diego, Salmon's team has prepared 12 tip cards based on the Wildfire Zone Web site. The plan is to make these cards available in touch-screen information kiosks in places such as libraries and building supply stores. "We want to make it easy for them to get what they need," he says. "We don't want to overwhelm people with a 500-page book of information."

"As we get more houses in the wildland-urban interface, the impact of these wildfires will continue to grow," Salmon says. "They're never going to go away." — *Robin Meadows*

CAL FIRE/Wes Schultz

***Above*, firefighters attempt to protect a home from the Harris Fire in San Diego County, October 2007. *Left*, San Diego County Cooperative Extension developed a Web site to help prepare residents for wildfires (www.wildfirezone.org).**

Outreach aids Spanish-speaking firestorm victims

During the recent wildfires, the University of California's News and Information Outreach in Spanish (NOS) (http://espanol.ucanr.org) focused on working with UC Cooperative Extension (UCCE) staff in the affected areas to quickly provide information to Spanish-speaking firestorm victims. Their efforts included:

- Providing translations of fire-related materials for fire Web sites in San Diego and Los Angeles.
- With staff from the UC Division of Agriculture and Natural Resources' Consumer Economics program in Riverside, developing "Don't Get Burned Twice," a bilingual brochure with information on how to avoid being victimized in the aftermath of a firestorm. The brochure includes warnings about home repair fraud, charity fraud, phony "officials," advance fee loans and other schemes.
- Producing a special edition of Radio Noticias, the monthly CD distributed to more than 100 Spanish-language radio stations in California. The CD included 30 news and public-service messages on recovering after a firestorm, and tips to prepare for future natural disasters.
- Promoting AsisTel — the statewide toll-free service [(800) 514-4494] that provided assistance and critical information to the victims of the Cedar fire in October 2003 — to UCCE county offices, media and relief agencies. The message-on-demand service features information on recovering after a fire, completing insurance claims, food safety during a power outage, dealing with exposure to smoke and ashes, and other fire-related topics.

Photos: Morgan P. Doran/UCCE Solano County

***Far left*, one dose of lithium chloride gives sheep a mild stomach ache and trains them to avoid grapevines and focus on the weeds below. *Top left*, a vine grazed by trained sheep; *bottom left*, the same vine grazed by untrained (control) sheep.**

Trained ovines chomp on weeds, avoid vines

TO most vineyard managers, any plants growing directly under grapevines are nasty weeds that can rob the crop of water and nutrients. But to sheep, these weeds are tasty and nutritious forage. This would make sheep (ovines) ideal for controlling vineyard weeds except for one thing — these herbivores like grape leaves just as much.

Some managers get around this problem by using miniature "babydoll" sheep that are too short to reach grape leaves. However, while effective, these sheep are also expensive. Other managers use sheep only when the grapevines are dormant, but this means switching to other weed control methods that have their own drawbacks during the growing season. For example, mowing entails increased fuel costs and soil compaction, and herbicides can contaminate surface waters (see page 19).

To find a better alternative, UCCE researchers are training sheep not to eat grape shoots and leaves. "We got the idea from a workshop on manipulating what animals eat," says project leader Morgan Doran, a Solano County livestock advisor. The workshop was by Fred Provenza of the Utah State University program BEHAVE, which stands for Behavioral Education for Human, Animal, Vegetation and Ecosystem Management (www.behave.net). This program focuses on how animals decide what to eat, and includes finding ways to encourage herbivores to eat invasive weeds and discourage them from eating desirable plants.

To train sheep, Provenza recommended letting them eat as many grape leaves as they wanted and then giving them a small dose of lithium chloride, which is harmless but causes a mild stomach ache. He also recommended training young sheep rather than adults. "You need to mold them at an early age, before they've had much dietary experience," Doran says.

First, the UCCE team did a pilot project on ewe lambs at UC Davis. These lambs had been raised on alfalfa pellets, and a single dose of lithium chloride was enough to make the lambs steer clear of grape leaves. Next, the team moved on to a field study of 40 range-raised lambs at the UC Hopland Research and Extension Center. These lambs were used to eating a variety of plants, and getting them to avoid grape leaves required an additional, slightly higher dose of lithium chloride (still well below toxic levels).

The sheep aversion training has been remarkably effective. Nine months after their lithium chloride doses, the 40 Hopland sheep still ignored vigorous growth on grapevines right in front of their faces, preferring to munch on the weeds growing beneath the vines. "They were comparable to normal floor management," Doran says.

However, the possibility remains that even trained sheep will eventually balk at eating some vineyard floor plants and try grape leaves again. "It depends on the grazing management," Doran says. " If they don't have enough feed or enough palatable feed, they will transition from floor vegetation to grape leaves."

So far the researchers haven't found any weeds that the trained sheep don't like. But there are cover crops that sheep don't enjoy. "Some clovers, such as balansa, are bitter in the spring, which made the sheep start nibbling on grape leaves," Doran says. He recommends subterranean clover and ryegrass as good cover crops for trained sheep.

Besides benefiting vineyard managers, using sheep to control weeds could also help sheep producers. Weed-eating sheep would reduce forage costs and give producers the new market of renting out their flocks' services. "The lamb market oscillates up and down quite a bit, and this could give sheep producers a more secure source of income," Doran says.

— Robin Meadows

Mapping shows continued vineyard expansion in premium wine-growing areas

Photos: Courtesy of Adina Merenlender

Aerial photography and mapping show that the increased demand for premium wines is reflected on the ground in Sonoma County (see page 12). There, as in other coastal counties, vineyard acreage increased dramatically during the 1990s and into the early 2000s.

"While expansion rates have decreased in Sonoma County in recent years, mapping of vineyards from aerial photos and analysis of data published by the county agricultural commissioner show that new vineyards continue to be planted," says Emily Heaton, doctoral student in the UC Berkeley Department of Environmental Science, Policy and Management. Heaton has been mapping Sonoma County vineyards from aerial photos as part of her work in the lab of Adina Merenlender, Associate Cooperative Extension Specialist.

Their research, which is affiliated with the UC Integrated Hardwood Range Management Program, focuses on the environmental impacts of habitat conversion. "Knowing the location of vineyards and other land cover types helps us research the impacts of land use on the environment," Merenlender says.

To obtain the most accurate estimates of vineyard acreage, the researchers use digital, orthorectified aerial photos from 1993, 2000, 2002, 2004 and 2005, as well as oblique aerial photos from 2006. The photographs are matched on-screen with mapped landmarks such as roads and hilltops, which ensures that the boundaries of mapped vineyards are spatially accurate.

The ongoing mapping effort shows that at least 5,160 acres of vineyards have been planted in Sonoma County since 2000. This represents 8.7% of the 59,000 vineyard acres that have been mapped so far. "While many new projects occurred in the more established premium-wine-grape areas such as Alexander Valley and Sonoma Valley, there has also been a significant increase in areas that were not historically important, such as the Sonoma Coast and land surrounding Petaluma," Heaton says.

Coastal areas with cool conditions favorable for pinot noir seem to be particularly attractive. Some observers call it the "Sideways" effect, due to the popular 2004 movie that touted California pinot noir. For example, for the portion of the Sonoma Coast appellation that lies north of the Russian River and west of Monte Rio, vineyard acreage increased by 351 acres during 2000–2006 to a total of 1,028 acres, a 51.6% increase. In addition, the clearing of forestland for additional vineyards is evident in 2006 imagery, Heaton says.

"Historically, the Sonoma Coast was not an important wine-grape region — only about 200 acres existed in the analysis area in 1993," Heaton says. "But a small number of vintners and wineries have proven that high-quality pinot can be grown successfully on the coast."

Merenlender adds, "The business environment for timber production has become a lot more difficult due to historic overharvesting, volatile wood markets and stricter environmental rules. A lot of coastal forest land is going up for sale, cheaply."

Coastal watersheds provide habitat for salmon, and vineyard conversions can alter natural water flows that are needed to support spawning and fish growth, Merenlender says. Vineyards often pump water from the ground during the dry season, potentially limiting survival of juvenile fish.

Recent vineyard expansion has also occurred in other coastal counties that produce premium wine-grapes. Based primarily on agriculture commissioner reports (not aerial mapping), Central Coast vineyard acreage expanded from an estimated 26,800 acres in San Luis Obispo County in 2000 to 36,493 acres in 2006, a 32% increase. Santa Barbara County's vineyard acreage increased from 9,542 acres in 1990 to an estimated 21,000+ acres in 2007.

On the North Coast, Napa County's vineyard acreage increased from 32,715 acres in 1990 to 45,136 in 2006. Lake County's acreage went from 7,335 in 2002 to 8,529 in 2005. Finally, in Mendocino County, acreage increased from 12,608 in 1991 to 16,446 in 2001 and 16,783 in 2006.

"We use this data on the rate and extent of land-use change to quantify environmental impacts and to forecast future land-use patterns, in an effort to improve conservation planning," Merenlender says. *— Editors*

Aerial photographs are used by UC researchers to evaluate land-use changes, such as the conversion of forest lands to vineyards. *Top*, the Sonoma Coast (no vineyards shown); *middle*, the mainstem of the Russian River surrounded by vineyards; *bottom*, a small reservoir among newly planted vines in Sonoma County.

RESEARCH ARTICLE

California wine industry evolving to compete in 21st century

by Rachael Goodhue, Richard Green, Dale Heien *and* Philip Martin

The California wine industry is growing and changing amidst a global revolution in grape growing, wine production, wine marketing and consumer tastes. California accounted for roughly 90% of the value of U.S. wine production in 2006. U.S. per capita wine consumption and the quality of wine consumed continue to rise. The largest California wineries have long accounted for most California wine shipments and continue to expand with respect to volume and number of labels. While small wineries sell most of their wine directly to end-users, many midsized wineries face challenges in an increasingly crowded marketplace.

California Association of Winegrape Growers/www.cawg.org

California's wine industry continues to grow and change. The state's 17 crush districts processed 3.5 million tons of wine grapes in 2006. The California Associate of Winegrape Growers is promoting viticulture statewide with its new "One Nation Under Vines" campaign.

IN 2006, almost 3.1 million tons of California grapes were crushed to make wine (CDFA 2007), enough to make more than 2.3 billion bottles. (A ton of grapes makes 150 gallons, or 750 bottles of wine; California wine grape yields were on average 6.5 tons an acre in 2006.) For wine grape purposes, California has 17 crush districts (fig. 1). Napa County (district 4), for example, accounted for 4% of the 2006 crush but received grower prices that were 5.5 times higher than the state average. Fresno, Madera and Tulare counties (district 13) accounted for one-third of the state's crush, while growers there were paid prices that were just over one-third of the state's average price (table 1).

The average price received by growers for grapes was $548 a ton in 2006, making the value of the grapes in an average bottle of California wine $0.75 (CDFA 2007). The range in prices was wide, from less than $300 a ton in the San Joaquin Valley, where half of California wine grapes are grown (making the grapes in a typical bottle from this region worth $0.40), to over $3,000 a ton in the Napa Valley ($4 a bottle). The average price per ton is generally lower in districts with the largest share of the crush. Few other commodities have 10-to-1 differences in grower prices and even wider retail price differences.

The California wine industry is growing and changing amidst a global revolution in grape growing, wine production, wine marketing and consumer tastes (Sumner et al. 2004; Anderson 2004). This article focuses on the marketing and taste factors that are producing a layered or tiered industry in which middle-sized producers are being pushed to get larger or smaller.

Three important trends are influencing the California wine industry: (1) increased production by multiwinery corporations with many labels that cover different price points, (2) the growth of small wineries that sell directly to consumers and (3) the resultant squeeze on midsized wineries. Economies of scale in marketing seem to explain the tendency of multiwinery corporations, including liquor producers and luxury-brand conglomerates, to buy midsized wineries and offer a variety of labels; meanwhile, wine-based tourism and direct sales via the Internet help explain the growth of small wineries. The future is uncertain for wineries producing too little wine to have extensive distribution and marketing activities, but too much to sell directly to consumers.

Wine consumption: More and better

California accounted for roughly 90% of the value of U.S. wine produc-

Many consumers visit small wineries, taste the wine and purchase it on the spot, which eliminates the need for distributor markups and shipping costs.

Fig. 1. California crush districts, 2006. See table 1 for each district's share of crush and revenue. Source: CDFA 2007.

tion in 2006, down from about 94% in 2000. About 80% of U.S.-produced wine is consumed domestically, so trends in American wine consumption are an important determinant of the success of the California wine industry.

The average annual consumption per U.S. adult increased from 2.1 gallons (10 bottles) in 1995 to 2.5 gallons in 2000, and to an estimated 2.9 gallons (15 bottles) in 2006 (Wine Market Council 2007). In spite of this growth in per capita consumption, Americans still drink relatively little wine compared to countries such as France or Italy, where adults drink six to seven times as much wine as Americans (Wine Institute 2007). Furthermore, U.S. wine consumption is concentrated among regular wine drinkers. The 30 million Americans who consume wine regularly drink 90% of the wine consumed in the United States, an average of 12 gallons, or 60 bottles a year on average (Wine Market Council 2007).

There have been three important changes in U.S. wine consumption over the past 2 decades. First, consumers everywhere have come to appreciate the quality of California wine, and more Americans are drinking red wine for health reasons. In November 1991, the TV program "60 Minutes" explored the so-called "French paradox," the fact that there appears to be less heart disease in France than the United States despite the high-fat French diet. The explanation that moderate consumption of red wine may prevent heart disease helped to interest more Americans in wine for health reasons.

Second, Americans upgraded their palates, with many moving from inexpensive jug wines with retail prices of less than $3 a bottle to better quality wines costing more, including popular-premium wines costing $3 to $7 a bottle, super-premium wines costing $7 to $14 a bottle, and ultra-premium wines costing over $14 a bottle. Third, Americans increasingly prefer the consistent taste of fruity wines produced in "New World" California, Argentina, Australia, Chile and New Zealand to the wines from "Old World" Europe, which can vary significantly from year to year.

The industry uses four retail price categories to classify wine (Gomberg-Fredrikson). The fastest growth in the volume of wine sold has been in the super-premium category, which now accounts for one-quarter of U.S. wine sales, followed by the ultra-premium category (table 2). The only decline has been in jug wine,

TABLE 1. Grape crush and average price per ton, California districts, 2006

Key (fig.1)	District	Grapes crushed	Average price	Share of crush	Share of revenue	Price vs. avg. price
		tons	*$/ton*	..... %		
	1	70,948	1,237	2	4	225
	2	35,153	1,236	1	2	225
	3	216,250	1,991	6	20	363
	4	152,777	3,043	4	21	555
	5	13,925	750	0	1	137
	6	20,589	1,014	1	1	185
	7	223,590	1,085	6	11	198
	8	199,607	1,111	6	10	203
	9*	47,451	393	1	9	72
	10	19,049	1,083	1	1	197
	11†	568,558	417	16	11	76
	12‡	271,904	288	8	4	53
	13§	1,132,229	203	32	9	37
	14¶	416,326	224	12	3	41
	15	1,080	916	0	0	167
	16	3,656	1,111	0	0	203
	17#	95,896	550	3	2	100
Total (tons)		3,488,988		100		
Volume-weighted average ($/ton)			548	100		

District details

Details about districts that do not include whole counties are shown below:

* District 9 includes Yolo County north of I-80 to junction of I-80 and U.S. 50, and north of U.S. 50; and Sacramento County north of U.S. 50.

† District 11 includes San Joaquin County north of State Highway 4; and Sacramento County south of U.S. 50 and east of I-5.

‡ District 12 includes San Joaquin County south of State Highway 4.

§ District 13 includes Kings and Tulare counties north of Nevada Avenue (Avenue 192).

¶ District 14 includes Kings and Tulare counties south of Nevada Avenue (Avenue 192).

\# District 17 includes Yolo County south of I-80 from Solano County line to junction of I-80 and U.S. 50, and south of U.S. 50; and Sacramento County south of U.S. 50 and west of I-5.

Source: CDFA 2007, tables 2, 6.

TABLE 2. U.S. wine consumption by retail price (750 ml bottle), 1995–2006

Wine category	Retail price	Cases sold									
		1995	1998	1999	2000	2001	2002	2003	2004	2005	2006
		millions (% total volume)									
Ultra-premium	Over $14	3 (3)	6 (4)	10 (7)	14 (10)	15 (10)	16 (11)	17 (11)	19 (12)	21 (12)	22 (13)
Super-premium	$7 to $14	10 (9)	21 (15)	25 (16)	25 (17)	26 (18)	29 (19)	30 (19)	33 (20)	38 (23)	42 (25)
Pop.-premium	$3 to $7	35 (29)	48 (34)	50 (33)	53 (36)	51 (36)	53 (35)	53 (34)	53 (33)	55 (33)	57 (33)
Jug wine	Below $3	69 (59)	68 (47)	66 (44)	55 (36)	53 (38)	53 (35)	56 (36)	56 (35)	53 (32)	50 (29)
Total		117	143	150	147	145	150	156	160	165	171

Source: Gomberg-Fredrikson Report.

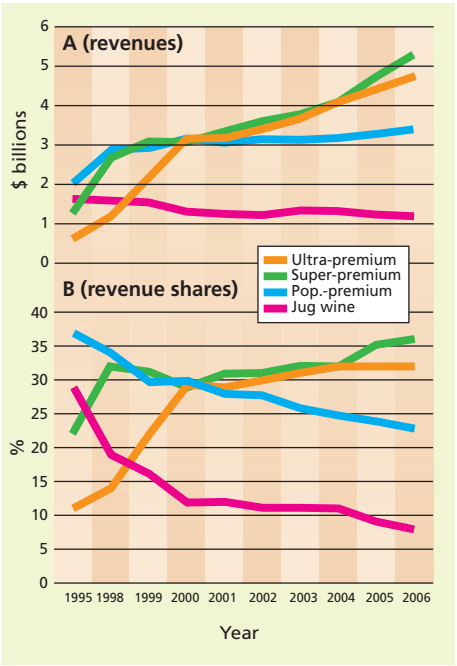


Fig. 2. U.S. wine (A) revenues and (B) revenue shares by price categories, 1995–2006.

whose sales dropped to less than one-third of the total.

Only the volume of wine sold is reported, not the revenue. We used the average retail price of a bottle of wine in each of the categories (assuming $18 for ultra-premium, $2 for jug wine and the midpoints for the other categories) to estimate nominal revenue: $5.6 billion in 1995, $10.7 billion in 2000 and $14.6 billion in 2007, as well as revenue shares (figs. 2 and 3).

Although prices rose over this period, some of the increase in wine revenue in the higher-price sales classes reflects inflation. The Economic Report of the President (2007) specifies that the consumer price index (CPI) rose from 152 in 1995 to 202 in 2006, an increase of 32%. In order to assess changes in the volume of wine reported in the various price categories (table 2), we corrected for inflation by calculating the Paasche and Laspeyres price indices since 1995. The Paasche price index weights prices using the most recent quantity of wine purchased (2006) in each category, while the Laspeyres price index weights prices using the oldest quantity of wine purchased (1995) in each category.

Using these indices, we found that wine prices declined 7.5% (Paasche) and 6.3% (Laspeyres) between 1995 and 2006. However, wine volumes and revenues are only reported by price category, so the Paasche and Laspeyres price indices do not fully reflect inflation. The price categories are constant in nominal dollars, not real dollars, so that a $3 bottle of wine in 1995 cost the same in real terms as a $3.97 bottle of wine in 2006 (moving it into the popular-premium category), a $7 bottle in 1995 cost $9.26 in 2006 (moving it into the super-premium category), and a $14 bottle in 1995 cost $18.52 in 2006.

If wine prices were uniformly distributed within categories, the inflation-adjusted share of super- and ultra-premium wines in 2006 (bottles selling for over $9.26 in 2006 rather than over $7) would be reduced from 38% to 30% of total wine sales. In other words, taking inflation into account only explains 8% of the increase in sales of super- and ultra-premium wines, so there is a substantial real increase in these categories compared to their 1995 share of 12%. The declining real price of wine likely contributed to the perception of wine as an "affordable luxury."

New World, Old World

While France, Italy and Spain still accounted for 51% of world wine production in 2004 (fig. 4), wine production has grown considerably in New World countries such as the United States, Australia, Chile, New Zealand and South Africa (IOWV 2005).

Americans seem to prefer the New World style of winemaking, which strives for a consistent taste from vintage to vintage, alcohol levels of 13% to 14% instead of 11% to 12%, and a fresh, fruity taste. New World wineries often grow their own grapes or have considerable control over vineyards, where grape vines are often planted close together, mechanical pruning and harvesting are common, and wineries bristle with technology. Yields are much higher in the New World. For example, Bronco Wine Company, whose 35,000 acres of vineyards make it the largest integrated vineyard-winery in California, produces Charles Shaw wine (sold only at Trader Joe's, a specialty food retailer) for $1.99 to $2.99 a bottle, as well as other labels such as Fox Hollow and Montpellier (Franson 2004).

In Old World Europe, most grape growers are small and most wine is made by cooperatives that crush locally grown grapes. Several varieties of grapes are usually combined to make wine, and the wine is labeled with the region in which the grapes were grown, such as Burgundy. A long list of rules governs how grapes are grown and wine is made, including irrigation restrictions that limit yields.

The complex rules that govern grape growing and winemaking must be followed to receive some of the €1.2 billion ($1.6 billion) a year in subsidies that the European Union provides to its wine sector. The European Union's overproduction of low-quality table wine, which is regularly distilled into industrial alcohol, has spawned plans to remove up to a million of the European Union's 8 million acres of wine grapes by providing up to €2.4 billion in payments to grape growers who remove their vineyards (Bounds 2007). The E.U. Commission has also proposed simplifying wine labels and allowing wineries to use

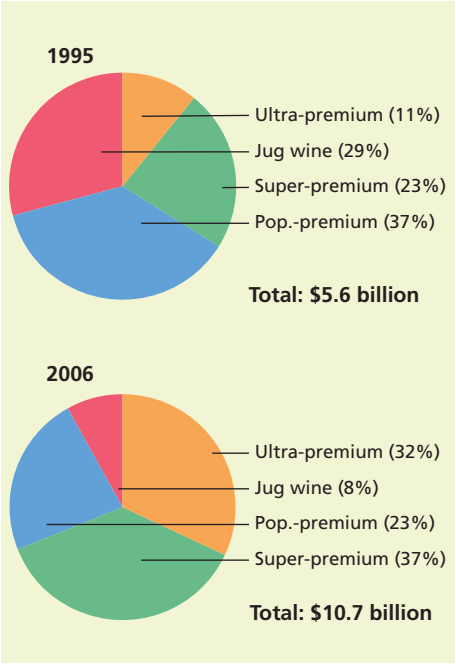


Fig. 3. U.S. wine revenue shares by price category in 1995 and 2006.

Australian Wine and Brandy Corporation

Australia is one of the world's top-10 wine-producing countries; its Yellow Tail brand is the leading U.S. wine import, with 12 million cases sold in 2007. *Above*, a harvest at Tyrell's Wines in Hunter Valley, north of Sydney in New South Wales.

New World winemaking techniques (EU 2007). Some growers in areas that historically produced lower-quality wines, such as Languedoc-Roussillon in southern France, are switching to single-varietal wines in an effort to attract consumers accustomed to New World labels, a strategy also spreading in Italy and Spain.

Rising U.S. consumption of wine has been accompanied by increased wine imports, which were up 186% between 1995 and 2006. Twenty-seven percent of the wine consumed in the United States is imported (table 3), including a rising share from Australia and Chile. These countries, with combined populations of less than 40 million, well under 1% of the world's population, produce over 6% of the world's wine, guaranteeing more New World wine exports.

In 1995, some 72.7% of U.S. wine imports were from France, Italy and Spain, the three largest Old World producers; by 2006, the world's three leading wine producers accounted for only 49.7% of U.S. wine imports (table 4). Imported wine accounts for 40% of the wine sold under $10 a bottle, in part because of the success of Australia's Yellow Tail, the leading import, which is on track to sell 12 million cases in 2007, almost 4% of the 300 million cases expected to be sold in the United States.

U.S. wine exports have also increased, up 177% between 1995 and 2006 (table 5). The United Kingdom and Canada have long been the leading importers of U.S. wine, but Italy was the third largest in 2006, up from negligible imports in 1995. Germany moved up slightly, from the sixth largest importer in 1995 to the fifth largest in 2006, and Switzerland and the Netherlands dropped out of the top five. While the relative rankings altered, it is important to note that all of these countries except for Switzerland increased their imports of U.S. wine in absolute terms.

Some wine is consumed in every country in the world, and at least 45 countries produce wine commercially. Does the prospect of more countries consuming more wine, and more wine being produced and traded, bode well for California producers? On the one hand, more locally produced wine may increase interest in wine, opening new markets for California wine. On the other hand, new countries could become major producers and competitors. China is an example of the opportunity and threat. More grapes are being planted and more wine is being made, but it is not yet clear whether China will emerge as a major market for imported wine or a major exporter of wine (Thach 2007).

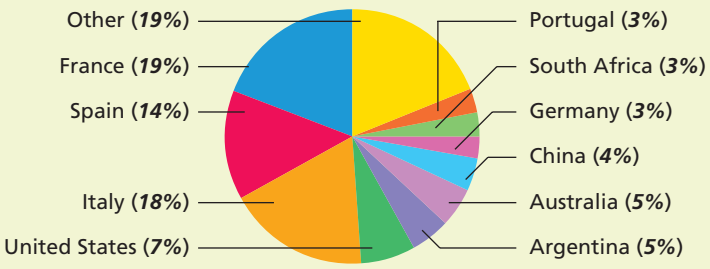


Fig. 4. Top 10 wine-producing countries by volume, 2004. Source: IOWV 2005.

TABLE 3. Share of wine entering U.S. distribution channels by source

Year	California	Other U.S.	Imports
	..... %		
1970	73	16	11
1980	69	10	21
1990	73	14	13
2000	69	10	21
2005	63	10	27

Source: Gomberg-Fredrikson Report.

TABLE 4. Top five sellers for U.S. wine imports, 1995 and 2006

Country	1995 Volume	1995 Total imports	1995 Rank	2006 Volume	2006 Total imports	2006 Rank
	1,000 liters	*%*		*1,000 liters*	*%*	
Italy	113,517	40.4	1	236,160	29.3	1
France	71,089	25.3	2	119,461	14.8	3
Chile	23,660	8.4	3	52,966	6.6	4
Spain	19,675	7.0	4	45,409	5.6	5
Australia	13,904	4.9	5	214,660	26.7	2
Total (top five)	241,845	86		668,656	83	
Total (all countries)	281,119	100		805,215	100	

Source: FAS 2007.

Consolidation, diversification

In general, the farm and food industries are consolidating so that fewer and larger firms account for an increased share of total sales. The number of U.S. farms, including wine grape producers, has been stable at about 2 million, but the largest 5% of U.S. farms account for an ever-increasing share of production and 60% of total farm sales in 2003. Similarly, the number of processors of farm commodities has been decreasing, so that the largest four meatpackers account for over 80% of U.S. meat production.

In the past decade, the number of California wine-grape growers has increased slightly to almost 5,000, and the number of wineries in the state, 2,900, has doubled in the past decade (the United States had 5,900 wineries in 2006, including 430 in Washington, 290 in Oregon and 220 in New York [Tinney 2007b]). However, growth in the number of grape growers and wineries can obscure more important changes within the California wine industry.

The largest California wineries have long accounted for most California wine shipments. The two largest wineries have accounted for about 45% of wine shipments over the past 15 years, the four largest for 60% to 65%, and the eight largest for about 75% of wine shipments. Total wine shipments have increased by almost 60% since 1990, meaning that the largest firms expanded significantly even though their market share was stable.

At the national level, concentration is slightly higher than at the state level, as the top three U.S. wineries accounted for about 60% of the 270 million U.S. cases shipped in 2006. E.&J. Gallo has been the largest U.S. (and California) winery for most of the past 75 years, producing an estimated 62 million (U.S.) cases in 2006. Constellation Brands is second, with about 57 million cases, and The Wine Group third, with 42 million cases (table 6). The top 15 wineries, each selling a million cases or more, accounted for about 85% of U.S. production.

The composition of some wine firms has changed as a result of acquisitions. Several of the wine producers that were among the 10 largest have been absorbed by larger firms, including Robert Mondavi and Vincor USA, top 10 wine producers bought by Constellation. Most recently, in November 2007, Constellation purchased the wine portfolio of Fortune Brands, which was the 11th largest producer. The smallest wine producers among the top 30, such as Wente and Sebastiani, each produce 300,000 to 350,000 cases a year. There are some economies of scale in production, because larger producers can get bottles and other materials more cheaply. But the major benefit of large size appears be in marketing, as large distributors and retailers can deal with one supplier for a wide range of wines.

The largest wineries offer a range of labels, from premium Gallo Family

ANR Communication Services

The number of wineries (currently about 2,900) in California has doubled in the past decade, providing diverse new choices for consumers. But industry consolidation continues apace, with the top three wineries now accounting for 60% of California wine shipments. Midsize wineries appear to be at greatest risk.

TABLE 5. Top five destinations for U.S. wine exports, 1995 and 2006

Country	Volume		Percent of total	
	1995	2006	1995	2006
	· · · 1,000 liters · · ·		*· · · % · · ·*	
United Kingdom	32,573	119,547	23	30
Canada	29,622	71,496	21	18
Japan	19,347	27,803	14	7
Switzerland	8,268	5,343	6	1
Netherlands	4,796	15,815	4	4
Top five	94,606	240,004	66	60
All countries	143,831	398,076	100	100

Source: FAS 2007.

ANR Communication Services

"New World" winemaking techniques — employed by countries such as the United States, Australia and Chile — emphasize consistency between vintages, economies of scale and modern technology (California winery shown). By contrast, "Old World" European winemaking is smaller scale and governed by complex rules.

Vineyards estate and Louis Martini wines to fighting varietals (bottles that use one grape variety and sell for $3 to $7 a bottle) such as Turning Leaf, to jug wines such as Carlo Rossi and Peter Vella. Gallo also distributes imported wines, such as Black Swan from Australia. Constellation, which bought Napa's Robert Mondavi winery in 2004, is the largest U.S. winery by revenue, since its wines include premium labels such as Opus One, Ravenswood, Estancia and Simi as well as the jug wines Almaden, Inglenook and Paul Masson. The Wine Group is the leading U.S. supplier of boxed wine (Franzia) and popular premium wines such as Glen Ellen, and is a leading supplier of bulk wine to other wineries.

The number of wine labels is rising faster than winery sales, that is, the percentage increase in labels is greater than the percentage increase in sales (Tinney 2007a). Almost 3,500 wine labels were available in supermarkets at the end of 2006, including almost two-thirds that were introduced after 1999. The top brands in grocery stores for the year ending July 1, 2006, were Yellow Tail, Sutter Home, Franzia, Woodbridge and Beringer California Collection. The proliferation of wine labels has reduced the average number of cases sold per label by about 20,000 a year.

Small wineries, those producing less than 5,000 to 10,000 cases a year, sell most of their wine directly to consumers. Many consumers visit small wineries, taste the wine and purchase it on the spot, which eliminates the need for distributor markups and shipping costs. By joining the winery's club, consumers can continue to purchase their favorite wines directly from the winery, and their loyalty can be cemented by inviting them to special events such as winemaker dinners. The U.S. Supreme Court in 2005 struck down laws that allowed in-state wineries to ship wine directly to consumers but barred out-of-state wineries from shipping to consumers within the state. As a result, states that allow shipments of wine to state residents from wineries within that state must now also allow shipments to consumers from out-of-state wineries. As states come into compliance with this ruling, direct sales to consumers are expected to expand.

TABLE 6. U.S. wine shipments, 2006

Rank	U.S. wine producer	Case shipments	Share of total shipments	Selected U.S. brands
		*millions**	*%*	
1	E.&J. Gallo	62	22.9	Barefoot Cellars, Gallo, Gallo Family Vineyards, Louis M. Martini, Turning Leaf
2	Constellation Brands	57	21.1	Almaden, Blackstone, Ravenswood, Rex Goliath, Robert Mondavi
3	The Wine Group	42	15.6	Cardinal Zin, Corbett Canyon, Foxhorn, Franzia, Glen Ellen
4	Bronco Wine Company	22	8.1	Charles Shaw, ForestVille, FoxHollow, Napa Ridge, Salmon Creek
5	Foster's Wine Estates	16	5.9	Beringer, Chateau Souverain, Meridian, St. Clement, Stags' Leap
6	Trinchero Family Estates	10	3.7	Folie à Deux, Montevina, Sutter Home, Terra d'Oro, Trinchero
7	Brown-Forman Wines	6	2.2	Bel Arbor, Bonterra, Fetzer, Jekel, Sonoma-Cutter
8	Diageo Chateau and Estate Wines	5.5	2.0	Beaulieu, Blossom Hill, Echelon, Monterey Vineyards, Sterling
9	Jackson Family Wines	5	1.9	Arrowood, Byron, Freemark Abbey, Kendall-Jackson, La Crema
10	Ste. Michelle Wine Estates	4.2	1.6	Chateau Ste. Michelle, Columbia Crest, Domaine Ste. Michelle, Erath, Snoqualmie

* A case of twelve 750 ml bottles = 2.4 gallons.
Source: Penn 2007.

Midsize wineries do not have the large brand portfolios at different price points that allow large multiwinery corporations to negotiate with distributors and wholesalers. Thus they do not benefit from economies of scale in certain aspects of production as do the large corporations. However, they have substantially more wine to market than small wineries do, increasing the difficulty of attempting to market their entire production directly to final buyers, such as consumers and restaurants.

The number of grape growers and wineries is increasing faster outside than inside California, although most non-California operations are small. The effects of the growing number of non-California wines on the state's wine business are as ambiguous as increased consumption and production around the world. The spread of wine trails and tasting rooms in other states, such as Iowa and Virginia, may raise consumer appreciation of wine, increasing the number of regular wine drinkers and stimulating demand for all types of wine, including California wine. Or, wine tasting may stimulate a demand among occasional wine drinkers only for local wines.

Whither California wine?

California wine has enhanced its quality and reputation with U.S. and global consumers. At the dawn of the 21st century, the interest of aging baby boomers in the lifestyle associated with wine and food, especially the interest of women and those convinced of wine's health benefits, augurs well for continued growth in an industry that is expanding premium wine production and direct sales to consumers. The University of California is contributing to the industry's competitiveness; most grape growers and wineries use rootstocks and technologies developed by University researchers.

Many midsized wineries face challenges in an increasingly crowded marketplace where the demise of midsized wholesalers makes it hard to keep their wine before consumers. These wineries, some with storied labels, may be in a race against time, hoping to be successful enough to be noticed and bought by a multiwinery corporation, or to achieve sufficient efficiencies in distribution to remain independent. Some may remain small and sell their wine directly to consumers or to local stores and restaurants. In this sense, the wine industry is likely to experience the kind of structural change that has occurred in farm production, where most farm commodities are produced by fewer than 5% of farms, and the smallest 90% of producers account for a small share of total production.

Jack Kelly Clark, UC Davis

The quality and reputation of California wine have improved in recent years, as has consumer interest in fresh, local food and wine. The expansion of premium wine production is likely to continue in California. *Above*, chardonnay grapes.

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Post-emergence herbicides are cost effective for vineyard floor management on the Central Coast

by Laura Tourte, Richard Smith, Larry Bettiga, Tiffany Bensen, Jason Smith *and* Daryl Salm

Central Coast growers are under increasing scrutiny and regulatory pressure to manage herbicide use because of their farmland's proximity to the Monterey Bay and National Marine Sanctuary. Vineyard floor management practices typically consist of a combination of weed control strategies, including herbicide use and cover crops. We evaluated nine combinations of vineyard floor management practices for their impacts on fruit yield, quality and costs. We found that compared to the grower standard, post-emergence herbicide treatments generally used smaller amounts of chemicals and were less costly, with similar yields and quality.

Vineyard floors are managed to prevent competition from vegetation that can inhibit grape yields and quality. *Top*, cultivated bare ground in the row middle; *bottom*, a cover crop.

Growers along California's Central Coast are under increasing pressure to keep herbicides from contaminating groundwater, and in turn, the Monterey Bay and National Marine Sanctuary. In vineyards, weed control generally consists of both pre- and post-emergence herbicide applications. The common pre-emergence herbicide simazine has been identified as a contamination risk for groundwater. This project was initiated to compare the long-term effects of floor management practices and alternative weed-control strategies on vineyard productivity over five growing seasons (2001 to 2005). In addition, we evaluated the associated economics over four growing seasons (2002 to 2005).

Vineyard floor management

Vineyard floors are managed to facilitate cultural practices and reduce competitive effects from noncrop vegetation. In California, key strategies for managing vineyard floors and successfully producing wine grapes are herbicide use, mechanical weed control and cover-cropping (Elmore et al. 1997; Ingels et al. 1998). These practices, used alone or in combination, must be considered carefully because they have both direct and indirect costs as well as production implications for wine grapes. A grower's selection of vineyard floor management practices is based on numerous factors including production philosophy, terrain, soil type, irrigation system, economics, risk management, and environmental and regulatory pressures.

Weeds compete with grapevines for water, soil nutrients and sometimes sunlight. Weed competition is most severe during the first 3 years of vine establishment, when root growth is limited. However, dense weed populations can also reduce growth and yields in well-established vineyards (Hembree et al. 2006). In addition, vineyards with high weed populations may require additional water and fertilizer to maintain production (Lanini and Bendixen 1992).

Cover crops may be either planted, or resident, vegetation in vineyard row middles. In vineyards, cover crops: benefit vine growth and productivity (Costello and Daane 1997; Hirschfelt et al. 1993); reduce nutrient loss and cycle nitrogen for crop growth (Christensen 1971; Hirschfelt et al. 1993; Bettiga et al. 2006); and improve soil structure and prevent erosion (Gaffney and van der Grinten 1991; Bettiga et al. 2006). Because growers recognize the importance of cover crops for producing grapes, reducing erosion and improving water quality, more than 90% of Central Coast vineyards are cover-cropped. However, due to the low rainfall in this area, cover crops are typically planted in narrower bands than in other parts of the state to reduce competition with the vines for soil water and nutrients.

Economics of grape production

The economic aspects of wine grape production add another layer of complexity to selecting floor management strategies. This includes evaluating:

(1) the cost and ease of implementing a practice, (2) the resulting weed population dynamics and their effect on crop yields and quality and (3) the level of risk or uncertainty associated with a technique, especially if it is a new or unknown technology (Bosch and Pease 2000). Growers use herbicides to manage risk because they reduce variability in management costs and yield, and therefore income, even though herbicide use may result in added costs in some situations (Olson and Eidman 1992). When multiple options for weed control exist, growers often consider trade-offs, or conflicting objectives that include direct financial costs and benefits along with indirect environmental and social costs and benefits, such as soil erosion and water quality (Wiles 2004).

This article examines how three weed management and three cover crop systems affect the costs of weed control in Central Coast wine grape production.

TABLE 1. Number of annual floor management operations and average costs, 2002–2005

Practice/treatments	Radius Weeder	Herbicide	Plant cover	Disk	Hand-weed	Side disk	Mow
Cultivation							
Bare ground	5–8*	—†	—	2–5	1–2	0–2	—
'Merced' rye	5–8	—	1	—	1–2	0–2	2–3
'Trios 102' triticale	5–8	—	1	—	1–2	0–2	2–3
Average number/year‡	6.5	—	1	3.5	1.5	1	2.5
Average cost/operation ($)§	8	—	33	6	96	6	7
Average cost/year ($)¶	52	—	33	21	144	6	18
Pre-emergence							
Bare ground	—	2–4	—	2–5	—	—	—
'Merced' rye	—	2–4	1	—	—	—	2–3
'Trios 102' triticale	—	2–4	1	—	—	—	2–3
Average number/year	—	3	1	3.5			2.5
Average cost/operation ($)	—	38	33	6	—	—	7
Average cost/year ($)	—	113	33	21	—	—	18
Post-emergence							
Bare ground	—	4–5	—	2–5	—	—	—
'Merced' rye	—	4–5	1	—	—	—	2–3
'Trios 102' triticale	—	4–5	1	—	—	—	2–3
Average number/year	—	4.5	1	3.5	—	—	2.5
Average cost/operation ($)	—	22	33	6	—	—	7
Average cost/year ($)	—	100	33	21	—	—	18

* Range for low and high number of annual operations.
† Operation not used.
‡ Average number of operations per year.
§ Cash costs rounded to nearest dollar.
¶ Based on number of operations and cumulative cash costs.

Management practices

Research site. The research was initiated in fall 2000, in a drip-irrigated vineyard near Greenfield in Monterey County. Greenfield has a Mediterranean climate, with annual rainfall ranging from 4 to 8 inches. The vineyard was established in 1996 with *Vitis vinifera* L. cv. Chardonnay on Teleki 5C (*V. berlandieri* Planch. × *V. riparia* Michx.) rootstock. Vine spacing was 8 feet between rows and 6 feet within rows. The soil was elder loam with gravelly substratum.

Experimental design. The in-row weed control treatments were: (1) cultivation, (2) post-emergence weed control only (glyphosate at 2.0% plus oxyfluorfen at 1.0%) and (3) pre-emergence and post-emergence weed control (simazine at 1.8 pounds active ingredient per acre plus oxyfluorfen at 1.0 pound active ingredient per acre; and glyphosate at 2.0% plus oxyfluorfen at 1.0%, respectively). Cultivations and herbicide applications were timed in accordance with grower practices and label rates. Cultivations were performed as needed during the growing season (March through October) using a Radius Weeder cultivator (Clemens and Company, Wittlich, Germany). Cultivation consisted of a metal knife held perpendicular to the direction of the tractor movement, and inserted slightly below the soil surface to sever weed shoots from their roots. Pre-emergence herbicides were applied with a standard spray rig in fall or winter. Post-emergence herbicides were applied in spring, summer or fall as needed with a Patchen Weedseeker light-activated sprayer (NTech Industries, Ukiah, Calif.); spray volume varied on a per-acre basis depending on weed cover.

Row-middle cover crop treatments were: (1) no cover crop (bare ground), (2) 'Merced' rye (*Secale cereale* L.) and (3) 'Trios 102' triticale (× Triticolsecale Wittm. Ex *A. Camus*). Cover crops were planted with a vineyard seed drill in the 32-inch centers of the 8-foot-wide rows just before the start of the rainy season in November of each year, from 2000 to 2005. Cover crops were mowed in spring to provide frost protection for the vines, and senesced in summer. Prior to planting cover crops each November, row middles were disked to incorporate the previous year's cover crop and stubble, and to prepare the seedbed. Bare-ground middles were kept free of weeds by periodic disking during the year (table 1).

Weed control (in-row main plot) and cover crop (row-middle subplot) treatments were arranged in a three-by-three split-block design with three replicate blocks covering a total of 23 vineyard rows, or 7 acres. Each block contained six vine rows and six adjacent middles. Weed control treatments were applied along the entire length of each vine row, which each had roughly 300 grapevines. Cover crop treatments were established along one-third of each middle and were continuous across the main plot treatments in each block. Each replicate main plot–by-subplot treatment combination included roughly 100 grapevines. Weed control data was collected under the vine rows (main plots) four to five times from spring through fall. Percentage vegetative cover and plant diversity were estimated using a line-intercept technique. Plant species intersecting points at 12-inch intervals along a 100-foot

The post-emergence treatment achieved adequate weed control without the high-risk herbicide simazine.

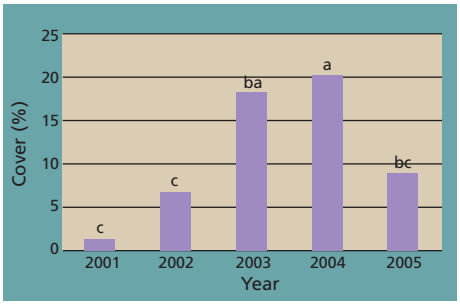

Fig. 1. Mean percentage cover of common purslane by year in the vine row in summer and fall weed evaluations. Bars with the same letter are not significantly different (Fisher's protected LSD test, $\alpha = 0.05$).

transect were recorded in each plot, or in 18% of each plot.

Statistics. Yield data and quality were analyzed using ANOVA with mean separation by Duncan's multiple range test. Multiple year analyses were performed by utilizing a split-plot design, with weed control as the main plots and cover crops as subplots. Analysis of variance was used to make across-treatment comparisons for the cover of key weeds.

Economics. Partial budget analyses were performed using Budget Planner Software for the four growing seasons from 2002 to 2005 for each of nine vineyard floor management practice treatments. Data was collected by main plot and subplot, transformed and reported on a per-acre basis for the timing of each operation, equipment type and use (including fuel, lubrication and repairs), material inputs (herbicides and seed), labor hours (machine and field) and interest on operating capital. Data was entered into Budget Planner, which generated tables estimating annual cash costs per acre for each treatment's operations and inputs. We also calculated the average cost per operation and per year, and annual and cumulative cash costs per acre by treatment.

Weed control

Because the grower had used the same weed control strategy since establishing the vineyard 4 years before our experiment began, the initial weed population was assumed to be uniform across the experimental site. However, over the course of the 5-year trial, the three weed control strategies developed distinct weed communities. In each case, weeds that were less susceptible

TABLE 2. Mean percentage cover of three selected weeds in each weed control treatment, summer and fall 2001–2005*

Weed control treatments	Common purslane	Horseweed	Yellow nutsedge
Cultivation	11.5a	0.2a	4.3a
Pre-emergence	0.7b	3.2a	7.3a
Post-emergence	0.1b	4.0a	4.9a

* Values within a column followed by the same letter are not different (Fisher's protected LSD test, $\alpha = 0.05$).

To assess the effectiveness of various vineyard floor management strategies, the authors compared pre- and post-emergence herbicide treatments with cultivation in the rows, and several different cover crops in the middle. The primary weeds in the Monterey County vineyard were yellow nutsedge, horseweed and common purslane.

to that particular weed control strategy increased, most notably common purslane (*Portulaca oleracea*), horseweed (*Conyza canadensis*) and yellow nutsedge (*Cyperus esculentus*).

Purslane. The cover of common purslane was significantly greater in the cultivation treatment than the post-emergence and pre-emergence treatments (table 2). In the cultivation treatment, this weed increased dramatically during the first 4 years of the trial (fig. 1). Purslane was likely able to produce large amounts of seed since it can set seed in as little as 3 weeks, and the weeds were only cultivated roughly once a month (Haar and Fennimore 2003). During the fourth and fifth years of the trial, increased field labor for hand-weeding was required to bring this weed under control and minimize its potential to compete with grapevines for water and nutrients.

Horseweed. The overall percentage cover of horseweed was not significantly different in any treatment during the 5 years of this trial (table 2). Both cultivation and pre-emergence applications of simazine and oxyfluorfen provided good control of this weed throughout the trial. However, by the second growing season, horseweed populations had increased in the post-emergence treatment (data not shown) due to inadequate control with glyphosate and oxyfluorfen. To bring this weed under control in the post-emergence treatment, it was necessary to include an application of glufosinate (at 3% v/v) in early summer 2002, and in late spring or early summer in all subsequent years.

Yellow nutsedge. The most troublesome weed in the pre-emergence treatment was yellow nutsedge, which was not controlled at all by the pre-emergence application of simazine and oxyfluorfen. Additional summer herbicide applications were used to manage this weed, which resulted in higher overall costs when compared to the post-emergence treatments. Because additional herbicide applications were made, the percentage cover of yellow nutsedge over the 5 years of the trial did not significantly differ from the other weed control treatments (table 2).

Crop growth, yield and quality

The weed control treatments that we studied had no effect on vine growth. While cover crop treatments also had no significant effect on vine growth overall, the 'Trios 102' triticale treatment significantly reduced pruning weights in 2001 and 2005. Pruning weights are a measurement of seasonal growth. The lowered pruning weights that we found may be due to the fact that the 'Trios 102' triticale grows later and so uses more soil water than the rye.

No differences in crop yields or fruit composition were measured from 2000 to 2005 that could be attributed to the weed control treatments. Cover crop treatments, when averaged over the 5 years, also had no significant effect on yield or fruit composition, although in 2001 and 2004 there was a reduction in berry size with the triticale treatment.

Cover crops may compete with grapevines for water and nutrients, and this competition may be beneficial or detrimental to vine productivity and fruit quality depending on the amount of soil moisture available during the growing season. In this study, it appears that irrigation management practices were able to overcome the impact of water use by the cover crop, and fruit production losses were avoided. Higher water costs may be associated with this result, however, and irrigation practices were not part of the economic analysis for this experiment.

Economic impacts

The effectiveness of in-row weed control or lack thereof affected the economics of each strategy. Costs varied by year in response to differing levels of weed pressure and the timing of weed control practices.

Annual cash costs. The three weed control treatments had similar annual cash costs per acre in the second and third years of the trial (fig. 2A). However, in the fourth and fifth years, costs for the cultivation treatment dramatically increased by $160 and $210 per acre. This result is explained by the steady increase in percentage cover of common purslane, which peaked in 2004, and the concomitant need for supplemental labor to hand-weed around the vines (figs. 1 and 2A).

In general, the post-emergence treatment was the least costly of the three weed control treatments. The exception was in the fifth year of the study, when the cost of the pre-emergence treatment was slightly lower (fig. 2A). This is because by the 2005 growing season, persistent horseweed populations presented particular control challenges, and resulted in the need for higher application rates of the more costly herbicide glufosinate.

Cumulative cash costs. The cultivation treatment had by far the highest

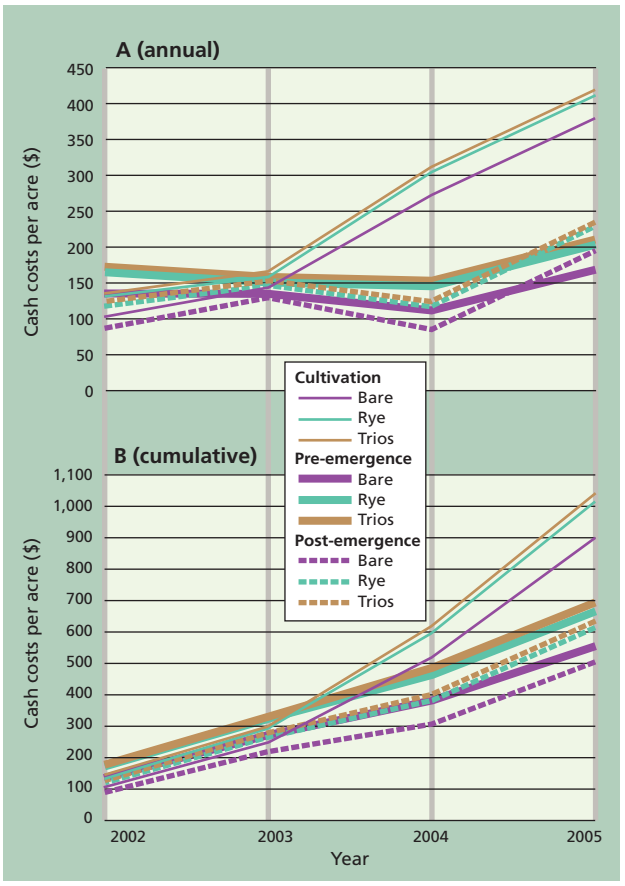

Fig. 2. (A) Annual and (B) cumulative cash costs per acre, by treatment.


There were no differences in vine growth, crop yields or fruit composition among all the weed control treatments in the 5-year study, demonstrating that vineyard floors can be managed effectively without high-risk herbicides. For the cultivation treatment, *above*, the Radius Weeder inserts a knife into the soil to sever weed shoots from their roots.

cumulative cash costs, ranging from $899 to $1,032 per acre over the 4-year study period (fig. 2B). The pre-emergence treatment had the next highest cumulative cash costs, ranging from $555 to $690 per acre. The post-emergence treatment was least expensive, at $498 to $633 per acre.

In total, the post-emergence treatments generally maintained good weed control and used smaller amounts of chemicals than the pre-emergence treatment. In addition, the post-emergence treatment achieved adequate weed control without the high-risk herbicide simazine used in the pre-emergence treatment.

Cover crop costs. Annual costs for preparing the ground and planting row-middle cover crops averaged $33 per acre per year in this trial (table 1). In years with low weed densities, cover crop costs ranged from between 20% and 30% of total floor-management costs; the cost range was lower in years with higher weed densities. The cost of planting and maintaining a cover crop in vineyards does not appear to dampen grower interest. In this production system, the cost of a cover crop may not be an annual expense because growers often manage cover crops to set seed, thus reducing the need to re-seed each year.

Choosing effective strategies

This production, weed control and economic information can assist growers in selecting practices and strategies for vineyard floor management. Weed control and cover crops have direct short-term financial costs and production implications; they have also been shown to have indirect and longer-term benefits for crop productivity, soil management, water quality and economic profitability. Affiliated research has shown beneficial impacts on nutrient cycling and soil microbiology (Baumgartner et al. 2005; Bettiga et al. 2006). This study has shown that weed control strategies without the inclusion of high-risk herbicides can be used effectively and economically to manage vineyard floors.

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RESEARCH ARTICLE

Minimum tillage could benefit California rice farmers

by Bruce Linquist, Albert Fischer, Larry Godfrey, Chris Greer, James Hill, Kaden Koffler, Michael Moeching, Randal Mutters *and* Chris van Kessel

Field research and grower interviews were used to evaluate the potential of minimum tillage for California rice systems. We found that by tilling only in the fall (instead of both the fall and spring), rice farmers can control herbicide-resistant weeds when combined with a stale rice seedbed, which entails spring flooding to germinate weeds followed by a glyphosate application to kill them. Our results indicated that yield potentials are comparable between water-seeded minimum- and conventional-till systems. We also found that rice growers can reduce fuel costs and plant early. However, minimum tillage may require more nitrogen fertilizer to achieve these yields.

Butte County extension advisor Randal Mutters explains the differences in rice establishment systems to farmers at a field day at the California Rice Experiment Station.

Rice is produced on about 500,000 acres in the Sacramento Valley annually, making it the region's major crop. Rice is a cereal crop that has been grown in California since the early 1900s. It is grown in flooded soils, so it is ideally suited to the poorly drained soils common to much of the Sacramento Valley.

Most rice growers till both in the fall to incorporate rice straw and in the spring to prepare the seedbed. Typical spring tillage involves six to eight tractor passes that include chisel plowing, disking and planing before applying fertilizer, and rolling the field in preparation for planting. No-till rice systems are not likely to be successful in California because harvesting equipment can leave deep tracks in the field that results in poor rice establishment and weed problems. Fall tillage is necessary to level the field and incorporate rice straw, but minimum-till rice systems with no spring tillage may be an option.

Minimum-till systems are not new to rice and are being evaluated in the southern United States (Watkins et al. 2004) and Asia (Lal et al. 2004). In these areas, rice is grown in rotation with other crops such as soybean and wheat, respectively. In contrast, most California rice systems do not involve crop rotations due to the heavy soils on which they are grown. Nevertheless, there is increasing interest in growing rice in California with no spring tillage due to the potential for reduced fuel costs, earlier planting (which allows an earlier harvest, in turn helping ensure that fall rains do not interrupt operations), better control of herbicide-resistant weeds, and potential air-quality improvements due to reduced dust.

Herbicide-resistant weeds are one of the main problems threatening the long-term sustainability of California's rice-based systems. In fact, California rice has seven herbicide-resistant weed species, more than any other crop or geographic area in the United States (Heap 2007). Herbicide resistance has evolved in rice weed populations due to repeated use of the same herbicide, herbicides having the same mode of action, or herbicides detoxified by a common mechanism in plants and weeds.

Minimum tillage with a stale seedbed offers new opportunities to control herbicide-resistant weeds in California rice fields. The approach entails preparing a stale seedbed before planting by flushing or flooding the field with water to induce weed-seed germination, and then killing the weeds, usually with glyphosate. The choice between flushing or flooding depends on whether or not the field is infested with weeds that require water saturation to germinate. The soil is then left untilled to ensure that buried weed seeds are not brought to the surface to germinate. This combination of a stale seedbed and no spring tillage can currently control all types of herbicide-resistant weeds in California rice systems, because they are not resistant to glyphosate.

Minimum versus conventional till

An experiment was initiated in 2004 at the California Rice Experiment

In the absence of herbicides or a stale seedbed treatment, weeds such as smallflower umbrella sedge were a problem in the conventional system studied.

A stale seedbed treatment followed by a glyphosate application effectively controlled weeds in the minimum-till treatment; no other herbicides were necessary here in 2004.

Station (RES) near Biggs in Butte County, to evaluate crop establishment methods and their effects on rice yield, weed and pest populations, and nitrogen cycling. The experiment was set up as a randomized complete block design with four replications on 0.5-acre plots. In this paper we discuss two treatments: water-seeded conventional till and water-seeded minimum till with a stale seedbed. Water-seeding refers to broadcasting rice seed into a flooded field, a practice used by more than 90% of California rice growers.

In both treatments, the plots were tilled in the fall to incorporate rice straw and then flooded to encourage straw decomposition. The conventional-till treatment replicated the practice of most California rice growers, and entailed spring tillage (chisel, disk, roll), flooding and planting. The minimum-till treatment had no spring tillage but the plots were flushed with water to prepare a stale seedbed prior to planting. Both the conventional- and minimum-till plots were flooded and planted (broadcasting 150 pounds of rice seed per acre into the flood water) on the same day. The plots remained flooded until a few weeks before harvest.

Weed control. In the minimum-till treatment a stale seedbed was prepared, which entailed flushing the plots with water in April and then draining. After the weeds germinated, glyphosate was applied at a rate of 1.2 pounds acid equivalent per acre. Other than this, weeds in both tillage treatments were managed similarly during the growing season with the objective of obtaining full control. This was accomplished using propanil (6 pounds active ingredient per acre) and penoxsulam (1.2 ounces active ingredient per acre) applied at the four- to five-leaf stage of rice. This mixture of broad-spectrum herbicides with different modes of action is the currently recommended practice for managing herbicide-resistant weeds.

A 3,000-square-foot portion of each plot was left untreated to monitor weed recruitment and evaluate the effectiveness of the stale seedbed. In the minimum-till treatment, this area received glyphosate prior to planting but not the other herbicides used in the rest of the plot. In the conventional-till treatment, this area did not receive any herbicides. The number of weeds per square foot in these areas was determined from 10 randomly placed, square-foot quadrats in each plot at approximately the time of rice canopy closure (20 to 30 days after planting).

California rice has seven herbicide-resistant weed species, more than any other crop or geographic area in the United States.

Pests. Rice water weevil is the most important invertebrate pest of California rice. The larvae feed on rice plant roots and cause crop damage, but the severity of weevil infestations can be monitored based on the degree of leaf scarring by the leaf-eating adults. Adult weevil feeding was monitored from the three-to-five rice leaf stage. Larvae were counted twice (2 weeks apart) in 10 soil samples in all plots in July.

Fertilizer management. Fertilizer management varied between the two study treatments due to differences in water management and tillage. Phosphorus and potassium fertilizer were applied on all plots prior to permanent flooding. In the conventional tillage plots the phosphorus and potassium were tilled into the soil with the tillage operations, but in the minimum-till system it remained on the surface.

Nitrogen fertilizer (as urea) was applied at a rate of 150 pounds per acre, within the recommended range for rice (UCCE 2006). In the conventional-till system, the field remained permanently flooded and anaerobic, and all of the nitrogen was applied in a single dose incorporated 3 to 4 inches below the soil surface prior to planting. In the minimum-till system, since the soil was left undisturbed following the stale seedbed treatment, nitrogen fertilizer was applied on the soil surface instead of below it. Two-thirds of the nitrogen was broadcast on the surface just before flooding for planting, and the remaining third was broadcast between 40 and 50 days after planting.

Nitrogen fertility trial. To determine the most efficient nitrogen manage-

TABLE 1. Nitrogen rates, timing and yields (adjusted to 14% moisture) for conventional- and minimum-till treatments at Rice Experiment Station, 2004 and 2006

	2004					2006			
Tillage system*	Total nitrogen applied	Preflush†	Preplant	Top-dress PI‡	Yield	Total nitrogen applied	Preplant	Top-dress PI†	Yield
	lb N/ac				lb/ac	lb N/ac			lb/ac
Conventional	0	NA§	0	0	6,295b	0	0	0	4,057b
	50	NA	50	0	8,308a	100	100	0	9,081a
	100	NA	100	0	8,269a	100	50	50	8,678a
	150	NA	150	0	8,097a	150	150	0	8,960a
	200	NA	200	0	8,673a	200	200	0	9,405a
Minimum	0	0	0	0	3,539c	0	0	0	3,556c
	100	0	50	50	7,085b	100	100	0	8,663ab
	150	0	100	50	8,432ab	100	50	50	7,306b
	150	50	50	50	9,178a	150	100	50	9,728a
	150	50	100	0	8,305ab	200	200	0	10,110a

* In conventional till, all nitrogen fertilizer was incorporated; in minimum till, preplant nitrogen was applied on the surface. Yield means within the same system and year, followed by the same letter, are not significantly different (LSD 0.05).

† Nitrogen fertilizer applied before flush for stale seedbed treatment.

‡ PI = nitrogen fertilizer top-dressed between mid-tillering and panicle initiation.

§ NA = not applicable.

TABLE 2. Rice yields under different establishment practices with treatment rate of 150 lb N/ac

Tillage system	2004	2005	2006	Mean
	lb/ac (14% moisture)			
Conventional	9,511	7,295	7,923	8,243
Minimum	9,303	7,299	7,457	8,020
ANOVA	ns	ns	ns	ns

ment practices for each tillage system, a nitrogen fertility trial was conducted in 2004 and 2006. This trial included five 400-square-foot subplots within each plot (minimum and conventional tillage) to which no nitrogen fertilizer had previously been applied. The location of these subplots within the main plots changed each year to avoid the compounding effects of the nitrogen fertility treatments. Nitrogen fertilizer rates ranged from 0 to 200 pounds per acre in the subplots (table 1). In the conventional-till treatment, nitrogen was always applied as a single dose (with the exception of one treatment in 2006) and incorporated below the soil surface before flooding for planting. In the minimum-till treatment, nitrogen was applied either as a single dose or split between two doses.

Data analysis. All data were analyzed using Statistical Analysis System (SAS version 9.1) software. Main plot yields, weed data and water weevil data were analyzed using a randomized complete block design. The nitrogen fertility trial was analyzed using a split-plot design.

Grower interviews. In 2006, late rains prevented many growers from normal spring tillage operations and a few growers were faced with the option of no spring tillage, and planting late or not planting at all. In winter 2007, we did phone interviews with three growers who did not use spring tillage in 2006 — as many as we could find. The purpose was to compare results from our relatively small experimental plots with what growers found at the field scale. Growers were asked to compare their minimum-till field with an adjacent conventional field, and to answer questions about productivity, tillage practices, and weed and fertilizer management. Growers were also asked how they would improve the minimum-till system and if they thought it was economical.

Minimum tillage compares well

Similar rice yields. Yields in the minimum-till treatment were similar to the conventional-till treatment in all years. The highest yield was more than 9,300 pounds per acre in 2004, and the lowest was about 7,300 pounds per acre in 2005 (table 2). These annual yield fluctuations are in line with countywide fluctuations in California and reflect climate variation.

Better weed control. The minimum-till treatment was extremely effective in depleting weed populations from the upper soil layer and markedly diminishing weed emergence with the crop (table 3). When this practice was used, little weed control was needed after the glyphosate application. In fact, no additional herbicides were needed in 2004.

The most important rice weed in these systems during the study period was smallflower umbrella sedge (*Cyperus difformis*). On average for the 3 years, the minimum-till treatment suppressed smallflower umbrella sedge populations by 94%. Infestations by the aquatic ricefield bulrush (*Schoenoplectus mucronatus*) also became relevant ($P < 0.05$) in 2006, and were 91% suppressed under the minimum-till treatment (table 3). Water-seeding rice strongly suppressed both barnyardgrass (*Echinochloa crus-galli*), the main *Echinochloa* species in this field (there was also some early watergrass), and sprangletop (*Leptochloa fascicularis*) (data not shown). However, *Echinochloa* spp. populations became somewhat higher in the last year of the experiment, and the minimum-till treatment also exhibited potential for suppressing this weed.

Success with the stale seedbed technique depends on keeping the seedbed moist or highly saturated, depending on if aquatic weeds are present, and allowing sufficient time for weeds to emerge prior to the glyphosate application. In 2006, there was neither sufficient seedbed moisture nor sufficient time for substantial weed emergence. Consequently, few weeds were present when the glyphosate was applied. Even so, the minimum-till treatment was successful in controlling weeds, suggesting that leaving the soil undis-

***Top left*, complete no-till is unlikely to succeed due to heavy rutting during the rice harvest and the need to decompose rice straw. *Top right*, nitrogen fertilizer is applied to the main plot in the conventional water-seeded system. *Bottom right*, water moves across the minimum-till treatment prior to planting; the soil surface is firm, with grooves made by a roller. Notice the difference in soil conditions between minimum tillage and, *bottom left*, conventionally managed rice fields.**

turbed in the spring helped discourage weed emergence.

While the stale seedbed technique worked well when enough weeds had emerged prior to the glyphosate application, the late-emerging aquatic weeds ducksalad (*Heteranthera limosa*) and redstem/redberry (*Ammannia* spp.) were not well suppressed (table 3); in fact, ducksalad became an increasing problem over time in the minimum-till treatment.

Similar rice water weevil levels. There were no differences in rice water weevil levels between the conventional- and the minimum-till treatments in a given year, although there was a trend toward more weevils with minimum tillage. The weevils were present at low levels in all plots in 2005 and 2006. The incidence of adult feeding scars was higher in 2005 than 2006, with 15% and 7% of plants scarred, respectively. Likewise, larval densities, which peaked at 0.2 per sample in 2006, did not differ between the two treatments in any given year.

TABLE 3. Weed recruitment in conventional till with no herbicide and in minimum till*

	2004		2005		2006	
	Conventional	Minimum	Conventional	Minimum	Conventional	Minimum
	plants/sq ft					
Echinochloa	0.0 ± 0.0	00.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	1.0 ± 1.7	0.1 ± 0.2
Smallflower umbrellasedge	18.4 ± 10.4	0.2 ± 0.1*	137 ± 45.0	6.6 ± 2.7*	25.5 ± 18.1	4.6 ± 2.1*
Ricefield bulrush	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	18.7 ± 11.9	1.6 ± 1.5*
Ducksalad	1.7 ± 0.8	1.7 ± 0.8	4.1 ± 1.3	3.4 ± 1.6	5.8 ± 4.0	19.4 ± 10.6*
Redstem/ redberry	3.0 ± 0.0	0.4 ± 0.20*	6.5 ± 1.5	6.5 ± 1.1	12.1 ± 7.7	5.10 ± 3.2
P	< 0.01		< 0.01		< 0.01	

* For a given year and weed species, asterisks (*) indicate significant ($P < 0.05$) differences between conventional- and minimum-till weed densities. Values correspond to specific plot sections (weed recruitment areas) where glyphosate was applied (but no other herbicide was used).

Nitrogen management differs

When no nitrogen fertilizer was applied, the minimum-till treatment had smaller yields than conventional tillage (table 1). This is probably because minimum tillage had two flooding events while conventional tillage had only one. When soil is flooded and then drained, nitrate accumulates during the aerobic period but may be subsequently lost through denitrification during the following anaerobic period (Patrick and Wyatt 1964; Linquist et al. 2006). In response to added fertilizer, the results varied between years but suggested that minimum tillage requires more nitrogen than conventional tillage to reach similar yields. In 2004, the minimum-till treatment required three times as much nitrogen as the conventional-till treatment to achieve optimal yields (150 versus 50 pounds of nitrogen per acre, respectively). In contrast, in 2006 similar nitrogen rates in the two till systems resulted in similar yields.

Splitting the nitrogen fertilizer dose has previously been shown to increase its use efficiency (Broadbent and Mikkelsen 1968; Linquist and Sengxua 2003). However, that was not the case in the nitrogen fertility trial portion of this study. Splitting the 150 pounds of nitrogen per acre in 2004 did not affect yields. This may be because this nitrogen rate exceeded that required for optimal yields, masking any increases in use efficiency. Splitting the 100 pounds of nitrogen per acre equally in 2006 actually resulted in lower yields than a single application of this rate at planting. However, it is possible that higher yields would have resulted from an unequal split, such as 75 pounds of nitrogen per acre at planting and 25 pounds per acre 40 to 50 days after planting.

The nitrogen fertility experiments were not conclusive, and further research is warranted. However, some general conclusions can be drawn based on our results. First, the additional flush of water in the minimum-till system will likely result in the loss of native

TABLE 4. Summary of three growers using no spring tillage and water-seeded rice systems

Operation	Grower 1	Grower 2	Grower 3
County	Colusa	Glenn	Colusa
Straw and winter flood	Baled/tilled/unflooded	Chopped/flooded/stomped	Incorporated/flooded
Stale seedbed	Yes	Yes	No
Planting date	April 26	May 3	May 2
Variety	M401	M401	M202
Seeding rate	20 lb/ac more	Same	25 lb/ac more
Yield	7,100 lb/ac	9,000 lb/ac	7,600 lb/ac
Yield relative to other fields	Similar	Similar or better	Less by 600 lb/ac
Main weed species	Sprangletop/redberry/watergrass/SFU*	Watergrass/SFU	Watergrass/sprangletop/SFU/redberry
Weed species	Same	Same	Same
Weed severity	Less	Same	Less
Herbicide use	Lower rates	Different program	1 less herbicide application
Fertilizer	4 top-dress	3 top-dress	3 top-dress
Total nitrogen applied	153 lb N/ac	140 lb N/ac	210 lb N/ac
Tractor passes	6 less	8 less	7 less
Air passes	3 more	4 more	3 more
Main problem	Fertility	Algae and ducks	Ducks
What would the grower do differently?	More fall land preparation; improved fertility management	Incorporate straw in fall and do more tillage	More fall land preparation and put in field ditches for better water management
Grower's economic assessment	Better	Better	Same

* SFU = smallflower umbrella sedge.

soil nitrogen. Second, nitrogen fertilizer in the minimum-till system is applied to the soil surface, where it is used less efficiently (Mikkelsen and Finfrock 1957; Broadbent and Mikkelsen 1968). Both of these factors suggest that the minimum-till system will require a higher nitrogen rate to maintain yield levels. While we can not determine a precise rate from our data, it appears that minimum tillage requires approximately 50 pounds of nitrogen per acre more than conventional tillage. This is based on the 2004 response and the fact that in both years the zero nitrogen yields were lower in the minimum-till treatment, which suggests a loss of native soil nitrogen.

Grower experiences

Three growers were interviewed who established rice using water-seeded practices (aerially broadcasting seed into flood water) in 2006 onto fields where there had been no spring tillage (table 4). In all cases, the growers incorporated rice straw or stubble in fall 2005 either by disking or wet rolling. Winter flooding varied between the fields but due to a wet winter, all were flooded for at least a portion of the winter. Growers 1 and 2 used a modified stale seedbed in which late spring rains germinated weed seeds (as opposed to flushing with irrigation water) and glyphosate was used to kill the weeds before flooding the field to plant. Grower 3 aerially broadcast rice seed into water from the winter flood period and drained the field shortly after planting. In all cases, nitrogen was applied aerially in three to four applications. Total nitrogen was comparable to what each grower normally applied and ranged from 140 to 210 pounds per acre.

One issue raised by the growers was fertilizer management, specifically how and when to apply nitrogen and phosphorus. Results from the on-station (RES) study suggest that only one or two nitrogen fertilizer applications are necessary. Also, phosphorus should be applied in the fall and incorporated because surface phosphorus applications may result in an algae problem, which grower 2 experienced.

Despite the late spring rains, all three growers were able to plant early, before May 3 (most rice is planted from May 1 to June 15). These were the first planted fields in their respective areas, and as a result, growers reported some rice seed predation by ducks. While two of the three growers used slightly higher seeding rates than the recommended 150 pounds per acre, data from the on-station experiment suggests that this may not be necessary. Two of the three growers reported that yields from their minimum-till fields were comparable to or better than their other fields. However, grower 3 reported that yields were about 600 pounds less per acre. These lower yields may have been due to phosphorus deficiency since none had been applied, although this grower typically did apply phosphorus fertilizer. A second possibility for this lower yield is that rather than draining the field following the winter flood, grower 3 retained winter flood water until after planting, which may have lowered soil oxygen levels and resulted in poor crop establishment.

The predominant weed species found in the minimum-till fields were similar to those typically found by these growers (*Echinochloa* spp., sprangletop, smallflower umbrella sedge and redstem/redberry), and the severity of the weed problem was similar to or less than normal. The two growers using a stale seedbed reported that the rains germinated weeds, which they were able to kill with glyphosate. All growers reported that either lower rates of herbicides, fewer applications or a different program was used on their minimum-till fields. On-station research showed that the stale seedbed system was able to control much of the weed problem (table 3). However, research is needed to better understand how long soils should remain moist or flooded and what temperatures are required to germinate specific weed seeds.

Benefits and drawbacks

All three growers interviewed reported that the economic benefits of minimum tillage were similar to or better than their conventional-tillage practice, and some said they might try it again. The main reason was that minimum tillage resulted in six to eight fewer tractor passes, which amounts to a fuel and labor savings of $120 per acre (Williams et al. 2001). However, some of these savings were offset by the ad-

***Left*, within each of the main plots, nitrogen fertility plots were established to determine appropriate nitrogen rates and management strategies. *Middle*, a stale seedbed following a flush, with weeds beginning to emerge. *Right*, once the weeds have completely germinated they will be killed with a broad-spectrum herbicide.**

ditional air passes required to apply glyphosate and fertilizer. Based on research from the on-station experiment, growers could apply fertilizer once or twice instead of the three to four times that they reported. Growers also indicated that if they were planning on no spring tillage, they would do more tillage in the fall, which would further offset the economic benefits. In addition to possible economic benefits, one major benefit was that growers were able to plant early despite late rains.

One drawback of the minimum-till system is the increased amount of nitrogen required to maintain yields. Since nitrogen must be applied on the surface, it is more susceptible to denitrification losses. This can have the effect of reducing the economy of these systems (urea nitrogen costs between 40 and 50 cents per pound) and increasing emissions of nitrous oxide, a greenhouse gas.

Potential for minimum tillage

In both on-station research and grower fields, the minimum-tillage system maintained rice yields in the absence of spring tillage. Where does minimum tillage fit in to a grower's overall farm-management strategy? First, minimum tillage can be useful when late spring rains prevent early planting under conventional tillage practices, as in 2006. Second, growers could employ minimum tillage to plant fields early. In such cases, additional tillage and phosphorus and potassium applications would be recommended in the fall.

Finally, minimum tillage can be used to control herbicide-resistant weeds by germinating weeds and subsequently killing them with glyphosate, an herbicide to which California's rice weeds are not yet resistant. Soil moisture must be carefully monitored and controlled because weed species require varying wet periods and temperatures for germination; this is an area of ongoing research. While glyphosate can currently control all types of California rice weeds that are resistant to other herbicides, glyphosate-resistant weed biotypes have evolved in areas of California where this herbicide has been used for many years (Simarmata et al. 2003). Therefore, glyphosate should be alternated with other herbicides, such as paraquat and glufosinate-ammonium, that are also lethal to herbicide-resistant rice weeds (Fischer 2002).

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RESEARCH ARTICLE

Postharvest survival of navel orangeworm assessed in pistachios

by Joel P. Siegel, L.P.S. (Bas) Kuenen, Bradley S. Higbee, Patricia Noble, Richard Gill, Glen Y. Yokota, Rodrigo Krugner *and* Kent M. Daane

Controlling navel orangeworm, a key pistachio pest, is problematic because the moth overwinters in "mummy" nuts. After harvest, there may be more than 30,000 pistachio nuts (mummies) left behind per acre. To provide better information for winter sanitation decisions, we investigated the number of available mummies and their levels of navel orangeworm infestation from winter through early summer in California pistachio orchards. Navel orangeworm mortality was highest from late December through mid-February, and was also higher on the ground than in trees. Mortality on the ground was highest when mummies were tilled or mowed with the groundcover than when nuts were left on the raised berm. Our data indicates that, in contrast to almonds, it is more productive to focus on clearing pistachios from the ground than on removing them from trees. However, winter sanitation procedures also should be augmented in order to destroy more overwintering navel orangeworm.

Navel orangeworm is a primary pest of pistachios and almonds in California. Eggs are laid on the exterior. When they hatch the larvae find cracks in the hull and burrow into the kernel.

More than 95% of U.S. pistachio production occurs in California, primarily in the central and southern San Joaquin Valley (CPC 2007). California pistachio acreage has almost doubled over the past decade to more than 152,000 acres, and pistachios were the second-most valuable California nut crop in 2004 at $438 million, trailing only almonds (Boriss 2005).

Pistachios are harvested mechanically, first by shaking nuts from the tree and then collecting them in a catch apron. But unfortunately for the grower, the entire crop does not make it to market. Some of the nuts remain in the trees after shaking, and some harvested crop is lost due to spillage (Siegel et al. 2004). Our research focused on the nuts that remain on the ground and in the trees after harvest, known as "mummies." They are costly not only because of their lost market potential but also because they are a resource for a key insect pest of pistachios: the navel orangeworm (*Amyelois transitella* [Walker]), a moth first described from specimens collected in Mexico (Wade 1961).

Despite its name, the navel orangeworm (NOW) is not a pest of navel oranges but rather a primary pest of California pistachios and almonds, as well as a serious pest of walnuts. Eggs are laid on the exterior of the nut or where the nuts attach to the stem. In some cases, if the hull has split and the kernel is exposed, eggs may be laid directly on the kernel. When the eggs hatch, the larvae crawl on the outside of the nut searching for a breach in the hull in order to gain entry and then burrow into the kernel. Navel orangeworm larvae cause direct damage by feeding on pistachio kernels, and indirect damage by increasing processing costs, reducing nut quality and facilitating aflatoxin contamination of nuts (Doster and Michailides 1994).

In both pistachios and almonds, there are multiple generations of navel orangeworm, and the population increases throughout the summer and early fall; consequently there are more moths in September than in July. The larvae and pupae that do not emerge from nuts spend the winter inside unharvested nuts, called "overwintering" (Caltagirone et al. 1968). Navel orangeworm develop intermittently in these mummies when the temperature exceeds 55°F (Engle and Barnes 1983), and oviposition can begin as early as mid-January on mummy almonds in Kern County. Although eggs laid this early are unlikely to develop successfully, those laid at the beginning of February can (Joel Siegel, unpublished data), and in most years emergence of adult moths to start the next generation is well under way throughout the San Joaquin Valley by mid-March. The later navel orangeworm generations, which emerge from August through September, are the most damaging to pistachios because pistachios become

At harvest time, *top*, pistachios are removed from the tree by mechanical shakers. *Bottom*, a tree collar captures the nuts.

During the pistachio harvest, nuts that are not collected either fall on the ground or are left in the trees. These leftover "mummy" nuts can harbor navel orangeworm over the winter.

infested after the hull breaks down, exposing the shell and/or kernel (Beede et al. 1984; Bentley et al. 2005).

Because insecticides do not control the overwintering navel orangeworm population, it is suppressed by sanitation, a laborious process consisting of blowing fallen mummies from the berm (the area immediately surrounding the trunk, containing the irrigation lines) into the drive rows (the area between the tree rows), and then tilling these nuts into the soil. Growers may also shake mummies from the trees and then rake or blow the nuts into the drive rows to be tilled (UC IPM Online 2007).

While orchard sanitation successfully controls navel orangeworm in almonds (Zalom et al. 1984), its effectiveness in pistachios is variable. This is partly because pistachios cannot be readily shredded by tillage and may stick to the berm, and as a result cannot be blown into the drive rows for disking. As many as half of the nuts remain on the berm after blowing because moisture "glues" them to the soil (Siegel et al. 2004). Even when pistachios are successfully tilled into the soil, navel orangeworm larvae can emerge from nuts buried as deep as 6 inches (Bradley Higbee, unpublished data).

Even though unharvested pistachios provide the only available food and shelter for overwintering navel orangeworm populations, the fate of these mummy nuts and the overwintering navel orangeworm has not been extensively studied. We studied pistachio mummy and navel orangeworm prevalence from winter through early summer, using both normal sanitation and experimental ground-management practices.

Prevalence of mummies and worms

We conducted a series of three studies at S&J Ranch in Madera County from 2004 to 2007. During winter 2004–2005, a 40-acre pistachio block was selected after harvest and four rows were chosen at random. Within each row, samples of nuts were collected from the berm every three to four trees in December, February, April and June. In addition, two other rows were selected at random (0.25 miles per row) and all mummies were collected from the trees in December and February. A total of 175,350 nuts were collected in 2004–2005 from the ground and canopy. In the next study, conducted between April and June 2006, we assessed the prevalence of split nuts and collected 227,286 mummies from the berms in an 80-acre block, as described. In the final study, conducted between January and March 2007, navel orangeworm population density was assessed in a 160-acre pistachio block, and 359,087 mummies were collected from the berm, as described. Findings from all three studies are aggregated in the results presented here.

To calculate the prevalence of navel orangeworm, the mummies collected during all three studies were placed in

Definitions:
Processed pistachio nuts

Upon arrival at the processor, pistachios fall into two broad categories. The first is nuts containing kernels, "**filled nuts**," which in turn can be subdivided into **split** and **unsplit** nuts. About 75% of harvested nuts are filled nuts with split shells, based on data provided by Paramount Farming Company for 1998 to 2004 (> 1.7 billion pounds field weight). The second category is unfilled nuts or "**blanks**," which lack kernels. These nuts are removed during processing.

Tens of thousands of pistachios are spilled per acre after a typical September harvest.

Top, spilled nuts may end up around tree trunks. *Bottom*, by the following June, the nuts have deteriorated substantially.

The authors evaluated methods for managing spilled nuts, *top*, on the berm, and, *bottom*, in the rows.

5-gallon buckets covered with netting, each containing about 550 mummies. The buckets were held at 80°F and checked periodically for adult emergence, which could be seen through the netting. All adults were removed, their numbers recorded, and the days elapsed from collection determined. For each sample date, about 10% to 30% of the nuts were removed from the buckets and sorted by hand to determine the percentage of split nuts and blanks. The total number of nuts collected was multiplied by the percentage of split nuts in order to determine the true number of nuts available to navel orangeworm. This is more accurate than calculating infestation by simply dividing the adults by the total number of nuts collected, because closed-shell and blank pistachios cannot be infested.

Ground management practices

For our ground management study, pistachio mummies were collected on Feb. 19, 2002, from an orchard in Madera County. Four lots of 100 mummies each were dissected to determine navel orangeworm prevalence, which averaged 35.5 ± 2.5% per lot, and the remaining mummies (4,800) were used in an experiment conducted in a pistachio research block at the University of California Kearney Agricultural Research and Education Center in Fresno County.

Ground management in this block consisted of a pre-emergent herbicide application on the berm to keep this section weed-free, but vegetation remained in the drive row. Four treatments were investigated: (1) placing mummies on the berm; (2) placing mummies in the middle of the drive rows and not mowing them; (3) placing mummies in the middle of the drive rows and then mowing them; and (4) placing mummies in the middle of the drive rows and then tilling them.

Treatments were set in a randomized block design with six replications. Each treatment plot was a 10.76-square-foot section of the berm or drive row that was isolated by cages (wooden frames 10.76 square feet at the base and 3.9 inches high) that were covered on top by organdy cloth immediately after treatment and left open underneath. Two hundred mummies (an estimated 71 navel orangeworm per plot based on the prior dissection) were placed in each plot, and the cages were checked weekly for adult emergence.

Split mummies decrease

Immediately after harvest, nuts remain on the ground due to spillage. In 2003 — in a separate study not described here — we dissected 9,300 spilled nuts immediately after harvest and determined that the prevalence of splits was 65.1% (Siegel et al. 2004).

In most circumstances it is more economical to concentrate on removing or destroying mummies on the ground than shaking them from pistachio trees.

The percentage of split nuts observed on the berm in our three studies, 71% (table 1), was consistent with our previous work and also comparable to the average prevalence of split nuts in loads received by Paramount Farming Company between 1998 and 2004.

The recovery of split nuts decreases over time as more nuts fall from the tree, and by midwinter/early spring only 30.6% of the mummies collected in our three studies were split nuts. This occurs because more of the nuts remaining on the trees after harvest are blanks, which weigh less than filled nuts and are less likely to be shaken from the tree. This was confirmed in a previous study —

TABLE 1. Percentage split, unsplit and blank mummies, Madera County, 2005 and 2006

Sample period	Split	Unsplit	Blank	Nuts sampled
Harvest spillage, October	71.0	22.2	6.8	8,624
Mummy nuts, winter and spring	30.6	3.2	66.2	14,872

TABLE 2. Infestation based on adult emergence of navel orangeworm (NOW) from mummies collected in Madera County, December 2004–June 2005

			NOW infestation	
Collection period	Total nuts	Split nuts	Total nuts	Split nuts
	no.	*no. (%)*	·····% ·····	
Berm mummies*				
December	30,000	11,460 (38.2a)	7.60	20.0a
February	29,500	9,300 (31.5b)	1.50	4.6b
April	15,000	3,056 (20.4c)	0.10	0.5c
June	85,500	11,050 (13.0d)	0.04	0.3c
Tree mummies†				
December	9,250	3,352 (36.2a)	3.70	10.1b
February	6,100	1,000 (16.4b)	1.60	9.5b

* Data analyzed using multiple regression with orthogonal polynomial coefficients; means followed by a different letter are significantly different at $P < 0.0001$.

† Data analyzed using 2 × 2 contingency chi square; means followed by the same letter are not different at $P \leq 0.05$.

***Top*, navel orangeworm larvae feed on the kernels and increase aflatoxin contamination. *Above*, mummy nuts on the tree.**

not described here — conducted in Kern County in 2003, when 20 trees were selected at random after the first shake and the remaining 280,500 nuts were removed, sorted and dissected by hand to determine the percentage of split nuts (38.1%). This is roughly comparable to the 30.6% split nuts recovered from the berm in our three studies between mid-winter/early spring.

The prevalence of split nuts continued to decline, and by mid-June 2005, only 13% of the mummies in our studies were split (table 2). In contrast, split nuts accounted for almost 43% of the mummies collected in the same orchard in June 2006, following a dry January and February (data not shown). The seasonal decline in split-nut recovery from the berm is due to a host of factors including germination, rotting, animal feeding and the continuous fall of blank nuts to the ground. Undoubtedly, differences in rainfall timing affect the rate of nut decomposition as well.

We could not assess seasonal changes in split nuts in the trees after February because by April there were few mummies remaining on the trees during the years studied. We obtained a rough estimate of the number of split mummies per acre by combining our data with previously published data on the average number of pistachios per tree. Pistachios are alternate bearing, which means that there is an "on" year of high nut production followed by an "off" year where production may drop as much as 60%. Goldhamer and Beede (2004) reported that mature trees in an "on" year produced an average of 12,000 nuts (74% filled, 26% blank) in Kings County during the 1991–1992 growing season. Today, a mature tree produces approximately 15,000 nuts in an "on" year, due to improved management practices. Based on the industry average of 135 trees per acre, during an "on" year an acre contains almost 2 million pistachios before harvest, of which approximately 1.44 million are filled (split and unsplit nuts). Assuming 90% harvest efficiency, the number of filled nuts left behind per acre after one shake is 144,000 per acre, most of which are split. If we assume that the maximum seasonal reduction in split nuts occurred in June 2005, an average orchard would contain 18,720 split nuts per acre (139 per tree) after harvest. If the prevalence observed in June 2006 was the minimum reduction, an average orchard would contain 54,000 split nuts per acre (401 per tree) after harvest was concluded.

Worm survival in mummies

Navel orangeworm infestation in split nuts collected from the berm declined by 77% between December 2004 and February 2005, while there was no decline in navel orangeworm infestation of tree mummies during this same period (table 2). Because adult emergence is minimal during this period, we attribute the decline in navel orangeworm density on the ground to mortality. After February, however, adult emergence is a factor. Distinguishing between mortality and emigration in the field is a common problem in all insect mortality studies because the cause of the disappearance in the population is unknown, except for instances when adult emergence is minimal or cadavers are recovered (Siegel et al. 1987).

In our 2005–2006 study, which focused on ground mummies, the decline in navel orangeworm preva-

TABLE 3. Estimate of density of split nuts and navel orangeworm (NOW) infestation per acre, December 2004–June 2005, Madera County*

Month	Split nuts			Navel orangeworm		
	Number	Stage decline	Cumulative decline	Number	Stage decline	Cumulative decline
		%			%	
December	38,586	–	–	7,717	–	–
February	31,818	17.5	17.5	1,464	81.0	81.0
April†	20,606	35.4	46.7	103	92.9	98.7
June‡	13,131	36.3	66.0	39	62.0	99.5

* Tree density is 95 per acre; initial input was 101,010 split nuts remaining after harvest.
† Decline in NOW was a combination of mortality and emigration due to adult emergence.
‡ Decline in NOW was a combination of mortality and emigration, but also with an input from oviposition.

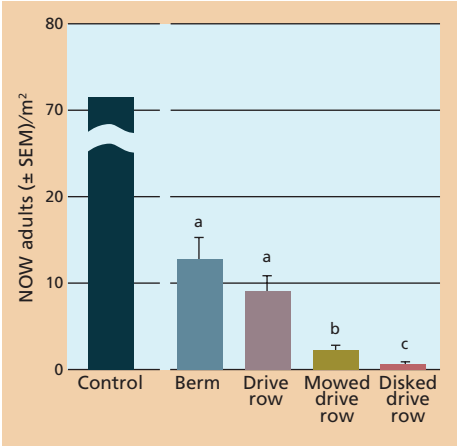

Fig. 1. Numbers of adult navel orangeworm emerging with four pistachio groundcover treatments. Treatment impact was determined using analysis of variance ($P < 0.0001$, df = 3,20, F = 21.761). Treatment separation, indicated by different letters above each bar, was determined using Fisher's least square difference test ($P < 0.05$).

lence between Jan. 9 and Feb. 6, 2006, was 60%, roughly comparable to our previous finding. Daane et al. (2001) conducted a study in Madera County in which 39,933 mummies were collected between late January and mid-April, and also in early June. Navel orangeworm infestation declined 22% between January and February, and 74.6% between February and March. We noted declines of the same magnitude in our study during that same period in 2006 and 2007. However, mortality is confounded with emigration: We know that the numbers of navel orangeworm decreased in the samples based on our recovery of adults, but we do not know if this decrease was due to adults emerging before nuts were collected in February and April or whether navel orangeworm died inside the nuts and therefore did not emerge.

Combining our data on navel orangeworm prevalence for 2004–2005 with information on seasonal changes in the density of available mummies, we estimated changes in navel orangeworm density within an acre of pistachios (table 3). This analysis assumed that all filled nuts are split nuts, and ignored infested tree mummies and emigration of adults. Assuming a 95 tree-per-acre planting containing 91 female trees, we begin with an estimated 101,010 split nuts after harvest. This analysis also included the sex ratio of navel orangeworm as a factor, in order to determine if the population would increase in the next generation.

We cannot assume a 50:50 sex ratio in adults emerging from pistachio mummies because the actual male-to-female ratio was 57:43 in both field-collected samples and laboratory studies (3,844 adults examined, chi-square analysis, $P < 0.0001$). Consequently, although we estimated the April population to be 103 adults per acre, only 44 of these adults are female. If we assume that a female lays an average of 85 eggs in her lifetime (Wade 1961), there are 3,765 navel orangeworm eggs per acre to begin the first generation of the new crop year. This first generation of the new crop year is laid between February and early June, with peak oviposition occurring from late April into mid-May. The population will increase if more than 2.7% of these eggs develop into adults, or if mortality is less than 97.3%. The navel orangeworm population will increase further if survival in the succeeding generations — which are laid on new crop nuts — exceeds 2.0%, because the sex ratio of adults emerging from new crop pistachios is 50:50.

Navel orangeworm larvae are more likely to survive in mummies than pupae. In a 2005 Kern County experiment — not described here — researchers at the Paramount Farming Company dissected 176,625 pistachio mummies collected in February and 66,802 mummies collected in March (Bradley Higbee, unpublished data). In February, 10,692 larvae were collected and 84.3% of these larvae were still alive, but only 14.7% of the 835 pupae collected were alive. In March, larval survival decreased slightly to 81.8% (2,445 total) while pupal survival significantly increased to 67.6% (587 total) (2 × 2 contingency chi square, $P < 0.0001$, in both cases). The higher larval than pupal survival indicates that pupae are more susceptible to unidentified mortality factors between February and March.

Ground management reduces NOW

In our ground management study active management such as mowing groundcover and disking nuts into the soil drastically reduced navel orangeworm emergence (fig. 1), although the extent of mortality arising from these practices may also be dependent on rainfall and temperature, which we did not measure. Additionally, disks that work the soil to greater depths will bury mummies further underground, increasing navel orangeworm mortality (Bradley Higbee, unpublished data).

To our surprise, however, there was no difference in emergence between mummies placed on the berm and in the undisturbed drive row (ground vegetation) where the ground vegetation was left intact. We hypothesize that moisture in the groundcovers increased mummy rotting, which in turn increased navel orangeworm mortality in undisturbed drive rows. This may not have occurred in this study, however, because our observation interval was too short or because the study year was relatively dry.

Controlling NOW in pistachios

We found that ground mummies are an important source of navel orangeworm, and that mowing and disking both the groundcover and nuts in row middles reduced navel orangeworm adult emergence. Moreover, burying the mummies kept females from laying eggs in them in the spring or early summer. In our experience, it is more economical to concentrate on removing or destroying mummies on the ground

To evaluate ground management practices, several hundred pistachio mummies were placed in each plot prior to treatment, and then covered with a wood frame to monitor the emergence of adult navel orangeworm.

Strategies for managing ground mummies include blowing them off the berm, and mowing and/or disking them into the soil to inhibit navel orangeworm egg-laying.

than to shake them from pistachio trees, given the limited resources available to most growers for winter sanitation. However, consistently removing mummies from the berm remains a problem, and in these studies navel orangeworm–infested mummies had higher survival on the berm than those in the row middles.

Our emphasis on removing mummies from the ground for sanitation in pistachios is in sharp contrast to current recommendations for sanitation in almonds, where it is considered critically important to remove mummies from the trees (Zalom et al. 1984; UC IPM Online 2007). Undoubtedly, the importance of pistachio mummies remaining in the trees will continue to be debated, and further research is needed to resolve this issue. Research is also needed to identify the mortality factors responsible for the decline in winter navel orangeworm populations on the ground. It may be possible to augment pistachio sanitation with insecticide use in the fall (Siegel, Higbee, et al. 2006) as well as with entomopathogenic nematodes (Siegel, Lacey, et al. 2006), which have been previously tested in almonds (Agudelo-Silva et al. 1995). Ultimately, navel orangeworm control will be improved by increasing our understanding of the population dynamics of this pest and by integrating preharvest management practices with postharvest sanitation.

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RESEARCH ARTICLE

Bait formulations and longevity of navel orangeworm egg traps tested

by L.P.S. (Bas) Kuenen, Walt Bentley, Heather C. Rowe *and* Brian Ribeiro

Standardization of pest monitoring practices and materials to maximize sensitivity to pest populations in the field is a foundation of effective integrated pest management (IPM). In response to changes in the availability of commercial bait material for navel orangeworm (NOW) egg traps, we evaluated potential alternative bait materials for use in monitoring this key pest of almonds, pistachios, walnuts and figs. Navel orangeworm egg traps baited with uninfested nutmeats were as effective as almond meal plus 10% crude almond oil, whereas traps baited with freeze-killed, navel orangeworm–infested nutmeats were less effective. The use of nut mummies (culled during winter orchard sanitation) as trap bait may not produce consistent results since the level of navel orangeworm infestation of these nuts is typically unknown. Three seasons of field tests showed that egg traps baited with almond meal plus 3% or 10% crude almond oil received similar numbers of navel orangeworm eggs, and these traps were equally effective for at least 10 weeks.

***Top*, a pistachio orchard in Kings County. *Above left*, an adult navel orangeworm pair mating on a pistachio; *center*, naval orangeworm lay their eggs on mummy nuts in the spring; *right*, egg traps are used in orchards to monitor navel orangeworm for integrated pest management.**

When navel orangeworm (NOW) infests nuts and figs, they will contain larvae or pupae and fecal material of the pest. Likewise, navel orangeworm infestation is highly correlated with the infection of nuts by *Aspergillus* spp., which produce carcinogenic aflatoxins. Both result in losses for growers.

Navel orangeworm (*Amyelois transitella*) larvae enter figs or nuts through open ostia (figs) or holes in damaged nut hulls (especially codling moth entrance wounds in walnuts); they also enter after hull-splitting and drying of almonds, pistachios and walnuts, which occurs normally as these nuts mature. It is believed that navel orangeworm lay eggs on susceptible hosts in response to changes in odors — associated with the physical maturity changes — emitted from the nuts and figs, and possibly in response to altered tactile cues associated with these physical changes. The host odors are attractive to female navel orangeworm, which then lay eggs on the host; mated navel orangeworm females are known to fly upwind to odors from crude almond oil (CAO) (Phelan and Baker 1987).

The ability to monitor pests is a key component of any integrated pest management (IPM) program. The navel orangeworm is a primary pest of about 1.1 million acres of nuts and figs in California, and currently it is monitored by direct counts of eggs or larvae on the host and by navel orangeworm egg traps (Rice et al. 1976). Trapping data is used to time the early harvest of almonds prior to egg-laying by the third generation of navel orangeworm and for timing insecticide sprays for the third generation in pistachios (Bentley and Surber 1986). The more accurately navel orangeworm populations can be tracked, the better they can be managed, particularly with newer, reduced-risk insecticides that have shorter residual times or require more precise application timing to maximize their effect on navel orangeworm numbers. Although the sex pheromone for this insect has been reported (Coffelt et al. 1979; Leal et al. 2005; Millar and Kuenen 2005), it is ineffective in sticky traps compared to traps baited with unmated females (Kuenen et al. 2001; Millar and Kuenen 2006). Therefore, egg traps will remain important for years to come in the IPM of navel orangeworm.

Current commercial egg traps consist of plastic vials (3.375 inches by

1.625 inches, with three 1.125-inch, screened, round holes in the lower half of the vial) containing a bait attractive to navel orangeworm females, which elicits egg-laying on the surface of the traps. When first introduced, the traps were baited with a mixture of wheat bran, honey, glycerol and water. The traps' efficiency has since been improved by adding ridges around the traps, painting them black and changing the bait from a wheat-bran-based material to almond press cake (an almond-oil processing byproduct) (Van Steenwyk et al. 1986). These black traps, baited with almond press cake plus crude almond oil (10% by weight), have become a de facto standard for navel orangeworm monitoring.

However, in 1997 Liberty Vegetable Co. (Santa Fe Springs, Calif.), the provider of almond press cake, altered its almond-oil processing and now sells almond meal instead of almond press cake as a byproduct. In 2001, we initiated field tests to find the optimum blend of almond meal plus crude almond oil to attract navel orangeworm females, and used red wheat bran as a crude almond oil carrier for comparison. We also investigated the relative attractiveness of infested versus uninfested almond and pistachio nutmeats, because infested almonds are reportedly better attractants for navel orangeworm than uninfested nuts (Andrews and Barnes 1982).

Egg trap tests

Tests were conducted in almond, fig and pistachio orchards in Madera County during the 2001 to 2003 growing seasons. Navel orangeworm egg traps were purchased from Trécé, Inc. (Adair, Okla.) and were filled at least 75% with baits to ensure that the traps' windows remained covered with bait throughout the test periods (see also Van Steenwyk et al. 1986). Traps were suspended on branches about 5 feet above the ground in the outer half of the canopy, and treatments were placed in randomized complete block designs with five or more replicates per test. Each replicate block was laid out along tree rows with at least 65 feet between traps within the replicate blocks and at least 65 feet between replicate blocks (actual spacing was determined by tree spacings within and between rows). The first trap in each row was at least 165 feet in from the nearest orchard road. All test blocks consisted of areas with no orchard drive rows or any other open spaces within larger orchard blocks.

Typically, egg counts were taken at weekly intervals. After each count, traps were re-randomized by moving them one tree forward within the replicate, and then the last trap in the row was moved to the first trap position in the same row. Trap baits were always formulated in the Kuenen lab, but plot specifics and the choice of orchards were conducted independently by our labs to ensure adequate orchard representation.

Data were analyzed graphically and by ANOVA. No data transformations were necessary as indicated by Bartlett's test for homogeneity of variances (Sokal and Rohlf 1981). Egg counts (eggs/trap/week) were analyzed by 2-way ANOVA using PROC GLM in SAS, and mean separation tests (alpha = 0.05) were conducted with Tukey's HSD test (SAS 2001). No significant block effects were found in any of our studies ($P > 0.05$).

Nutmeats vs. almond meal plus oil

Since some growers and pest control advisors use nutmeats collected from orchard sanitizing procedures in their egg traps, our first test in 2001 compared traps baited with (1) almond pieces, (2) pistachio pieces, (3) navel orangeworm–infested almond pieces, (4) navel orangeworm–infested pistachio pieces, (5) almond meal plus 10% (by weight) crude almond oil or (6) left empty as control traps. For the infested nut pieces, navel orangeworm larvae had been freeze-killed (as they would be by users of culled mummy nuts).

There were no differences in trap catch among uninfested almond, uninfested pistachio or traps baited with crude almond oil ($P > 0.05$) (fig. 1), whereas traps baited with infested almond or infested pistachio pieces were significantly lower ($P < 0.05$) than uninfested almond pieces. The control traps received few eggs. Commercial bait is easier to handle and more easily standardized. Further, since the almond meal containing 10% crude almond oil was as effective a trap bait as the uninfested nutmeats, and since the components are easily manipulated, our subsequent tests focused on assessing the influence of varying amounts of

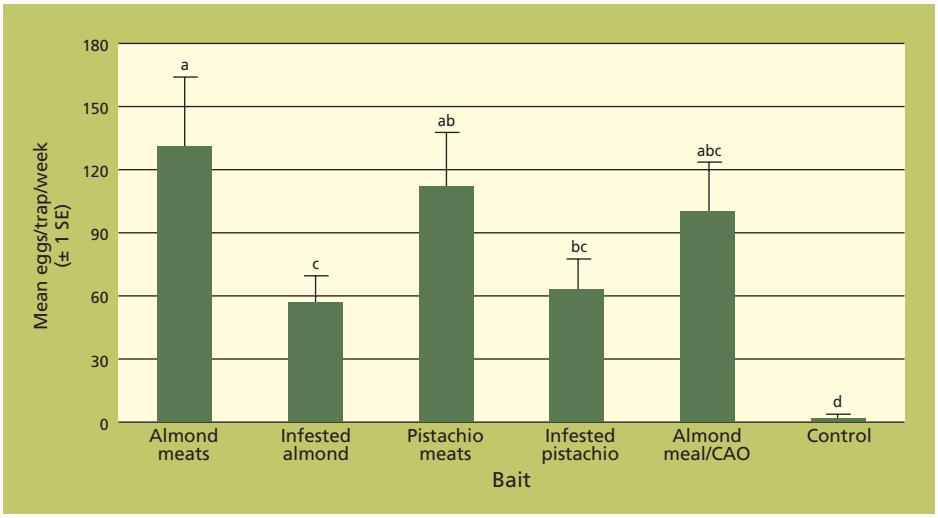

Fig. 1. Mean navel orangeworm (NOW) egg counts from traps containing NOW-infested almond or pistachio nutmeats, uninfested almond or pistachio nutmeats, almond meal plus 10% crude almond oil (CAO) by weight of almond meal, or unbaited controls. Traps were hung in a Madera County fig orchard March 26–April 30, 2001, with one trap per bait type in each of five blocks for a total of 30 traps. Traps were checked weekly. Bars represent ± one standard error. Columns having no letters in common are significantly different; $P < 0.05$, Tukey's HSD test.

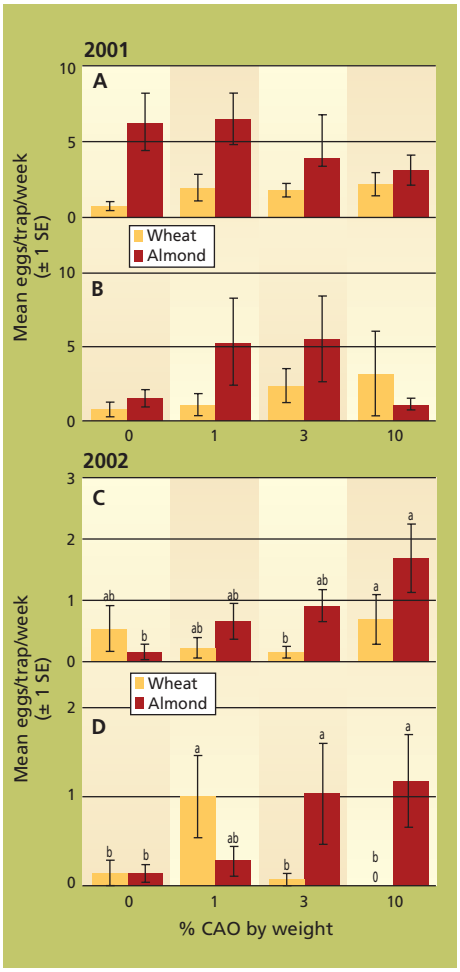

Fig. 2. Mean navel orangeworm (NOW) egg counts from egg traps containing almond meal or wheat bran plus crude almond oil (CAO). In 2001, traps were hung in a Madera County (A) almond orchard May 17–23 and checked daily, and (B) pistachio orchard July 11–Aug. 1 and checked weekly. In both orchards, one trap per bait type was hung in each of five blocks for a total of 40 traps. In 2002, traps were hung in a Madera County (C) pistachio orchard Aug. 8–Sept. 5, and (D) almond orchard Oct. 8–Nov. 5. In both orchards, one trap per bait type was hung in each of seven blocks for a total of 56 traps, and checked weekly. In 2001, there were no significant differences in egg counts within bait types. In 2002, columns having no letters in common are significantly different within bait types; $P < 0.05$, Tukey's HSD test. All bars represent ± one standard error.

Monitoring with egg traps allows growers to better time harvests and more effectively apply lower-risk insecticides. *Left*, a midseason pistachio cluster and, *right*, nuts mummifying after harvest.

crude almond oil plus almond meal on trap capture.

Standardizing trap baits

Comparisons were made between traps baited with almond meal or red wheat bran mixed with 0%, 1%, 3% or 10% crude almond oil by weight, based on the weight of almond meal. Thus, traps with a given percentage of crude almond oil contained the same amount of crude almond oil whether mixed with almond meal or the less-dense wheat bran.

Our first test with almond meal and wheat bran plus crude almond oil indicated that traps baited with almond meal plus 0% or 1% crude almond oil received more eggs than traps baited with almond meal plus 3% or 10% crude almond oil, and more than all wheat-baited traps ($P < 0.05$) (fig. 2A). In this first test, however, traps were checked daily, whereas in all subsequent tests eggs were counted weekly, which is typical for navel orangeworm monitoring.

A subsequent test in 2001 indicated that traps baited with almond meal plus 1% or 3% crude almond oil received more eggs compared to traps without crude almond oil or traps baited with wheat bran ($P < 0.05$) (fig. 2B). Overall, traps baited with almond meal plus crude almond oil received significantly more eggs than traps baited with wheat bran plus crude almond oil ($P < 0.05$). In 2002, we tested the same treatments but at different times during the growing season and in different orchards (which likely accounts for the lower numbers of eggs per trap compared to 2001). There was a clear trend for higher egg counts on traps with higher amounts of almond meal plus crude almond oil, whereas traps with crude almond oil on wheat bran showed no trend in trap capture in relation to the dosage of crude almond oil (figs. 2C, D).

In 2003, we conducted two further tests of almond meal plus crude almond oil only, since the wheat bran plus crude almond oil baits typically captured fewer eggs. Trap capture data were combined for the two tests and showed nearly equal trap catch at all doses of crude almond oil tested ($P > 0.05$) (fig. 3).

In this last study and our first with almond meal plus crude almond oil, the treatment without crude almond oil was as good as or better than those with crude almond oil. This is perplexing, since all the almond meal and crude almond oil came from single batches, respectively, from the vendor. It is also important to note that in all our tests, trap capture variability was high and mean trap catch in relation to the dosage of crude almond oil shifted continuously. Even with replicated and repeated tests, consistent significant differences were rare. Nevertheless, over the course of all tests, treatments with almond meal plus 3% crude almond oil typically performed well, so we are compelled to recommend it as the best treatment in this monitoring technique.

Trap bait longevity

In summer 2003, we also examined the longevity of trap baits. Fifteen traps were baited with 3% crude almond oil and 15 with 10% crude almond oil on

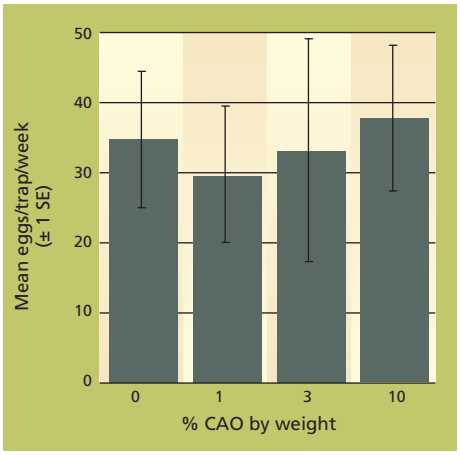

Fig. 3. Mean navel orangeworm (NOW) egg counts from egg traps containing almond meal plus crude almond oil (CAO). Traps were hung concurrently in a fig and pistachio orchard in Madera County May 20–June 26, 2003. In each orchard, one trap per bait type was hung in each of five blocks for a total of 80 traps, and checked weekly. Bars represent ± one standard error; there were no significant differences in egg counts.

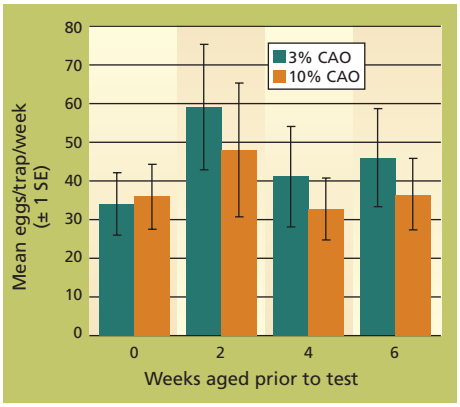

Fig. 4. Mean navel orangeworm (NOW) egg counts from egg traps containing almond meal plus 3% or 10% crude almond oil (CAO) by weight of almond meal; traps with baits had been aged 0, 2, 4 or 6 weeks in a laboratory incubator. Traps were hung in a Madera County pistachio orchard May 2–29, 2003. One trap per bait type was hung in each of five blocks for a total of 40 traps, and checked weekly. Bars represent ± one standard error; within bait types there were no significant differences in egg counts.

A new formulation of almond meal mixed with crude almond oil was an effective trap for navel orangeworm eggs. *Above*, female pistachio flowers.

almond meal, and aged (held) in a laboratory incubator at 90ºF. Every 2 weeks, five traps of each dosage were removed and held at –4ºF until we had traps that were aged at 90ºF for 0, 2, 4 and 6 weeks (–4ºF is a standard laboratory freezer temperature, at which little or no evaporation of odor compounds occurs). For this test, traps of all age categories were placed in a fig orchard when day-time highs were regularly 90ºF to 95ºF. Traps were positioned in a randomized complete block design and egg counts were taken weekly for 4 weeks. There were no differences in the capture efficiency of these aged egg traps ($P > 0.05$) (fig. 4) even after aging in the lab for 6 weeks and use in the field for 4 weeks.

Practical implications

Tests over three field seasons and in several orchards demonstrated that almond meal mixed with crude almond oil is an effective trap bait, and traps baited with a near-neutral carrier (wheat bran) plus crude almond oil were not as effective ($P < 0.05$). In addition, traps baited with pistachio or almond nutmeats were as effective as almond meal plus crude almond oil; however, freeze-killed, navel orangeworm larvae–infested nuts captured significantly fewer eggs ($P < 0.05$).

The variability in egg counts on the traps was always high, with the standard errors typically exceeding the means. Although significant differences in trap counts were rare among the almond meal/crude almond oil baits, traps with almond meal plus 3% or 10% crude almond oil tended to capture the greatest number of eggs, and both traps were equally effective over 10 weeks. We conclude that almond meal plus 3% crude almond oil will be effective in the field, with little or no loss of efficiency for at least 10 weeks.

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RESEARCH ARTICLE

Public work projects cultivate youth in workforce development programs

By David Campbell, Jean Lamming, Cathy Lemp, Ann Brosnahan, Carole Paterson *and* John Pusey

Using comparative case studies, we evaluated youth workforce development programs in California that are funded by the Workforce Investment Act (WIA) and implemented by local Youth Councils and Workforce Investment Boards. First, we identified a promising practice: skill- and pride-generating public work projects. Next, we identified three characteristics of these successful youth public work initiatives: (1) combining employment preparation with social services and personal support; (2) grouping youth in cohorts that work and learn together; and (3) providing caring adult supervision that combines discipline and support. Proactive investments in high-quality programs with these characteristics can reduce the growing number of out-of-school, out-of-work youth in California, save future public costs for the criminal justice and social service systems, and provide youth with meaningful employment opportunities.

Orange County Conservation Corps

Members of the Orange County Conservation Corps help remove nonnative plants and debris from coastal sand dunes on the Bolsa Chica Ecological Reserve in Huntington Beach, and restore the area with native plants. Federal funding for workforce development programs has declined from $24 billion in 1978 to about $6 billion in 2000.

For more than 2 decades, former Secretary of Labor Robert Reich (now a University of California, Berkeley, professor) has championed the idea that our national security depends on increasing public investment in education and workforce training (Reich 1983, 1991, 2002). In his 1991 book *The Work of Nations*, Reich wrote that rather than enhancing the profitability of its corporations or the worldwide holdings of its citizens, the nation's primary economic role is to "improve its citizens' standard of living by enhancing the value of what they contribute to the world economy . . . It is not what we own that counts, it is what we do." Given the changing nature of jobs in the new information economy, Reich argues for rethinking how we invest in public education and worker training. For example, today's workers often need to learn quickly on the job, think outside of the box, and understand other people's needs (Reich 2002), skills not measured by typical standardized tests.

Reich's vision for our nation's workforce provides a fitting vantage point for examining the findings of the recent UC Davis evaluation of workforce development programs for California youth, funded under the 1998 federal Workforce Investment Act (WIA) (see box, page 41). This evaluation found that the WIA's emphasis on comprehensive youth services results in higher quality programs, but that unfortunately these programs are reaching fewer and fewer youth due to a decline in federal funding (Lamming et al. 2006). Total public expenditures for training and retraining low-skilled workers diminished from a peak of $24 billion in 1978 to $7 billion in 1998 and a little over $6 billion in 2000, a 75% cut (Giloth 2004).

These federal cuts have hit California hard. Between 2001 and 2005, WIA allocations declined an average of 26% for 40 of the state's 50 local workforce areas (Lemp and Campbell 2005). These workforce areas are local administrative bodies that receive federal and state funding to implement workforce development programs. A 2006 survey found that two-thirds of the local workforce areas in California had experienced reductions in their allocations for youth programs over a 3-year period from 2003 to 2006 (Campbell et al. 2006).

These cutbacks exacerbate a growing youth workforce development crisis in California. A 2003 study reported that 638,000 California young people aged 16 to 24 years were out of school and out of work (Sum 2003). Too many of these youth end up in the prison system or, at best, in low-wage work that does not lift them or their families out of poverty. Existing youth workforce development programs reach a very small fraction of those in need. For example, a 2004 study reported that there were approximately 93,000 out-of-school, out-of-work youth in Los Angeles (Fogg and Harrington 2004). However, WIA-funded workforce programs enrolled

Youth programs emphasize comprehensive services

Youth workforce development programs are designed for young people 14 to 21 years old who face substantial obstacles to employment. These programs depend primarily on funding received under the 1998 federal Workforce Investment Act (WIA). Since 2000, state and local Youth Councils and Workforce Investment Boards have implemented such programs in California. Services are provided through contractors, including nonprofit organizations, city school districts, county offices of education, faith-related organizations and private firms.

Reflecting the belief of Congress that the "trend of providing short-term programs for youth is unacceptable" (Brustein and Knight 1998), WIA-funded youth programs have 10 required program elements: (1) tutoring, study-skills training and instruction leading to secondary school completion; (2) alternative secondary school offerings; (3) summer employment opportunities directly linked to academic and occupational learning; (4) paid and unpaid work experiences including internships and job shadowing; (5) occupational skills training; (6) leadership development opportunities; (7) supportive services; (8) adult mentoring; (9) follow-up services; and (10) comprehensive guidance.

Fig. 1. Local workforce areas selected for case study sample.

only 2,232 youth during the 2005–2006 program year due to insufficient funds (personal communication, California Employment Development Department administrative data).

A key goal of the UC Davis evaluation was to identify strategies that local workforce officials have developed to meet the broader WIA service mandate, despite decreased federal funding. We focus on one promising strategy worthy of replication, in which youth engage in skill- and pride-generating public work projects. Boyte and Kari (1996) defined public work as "work with public purposes, work by a public, [and] work in public settings." While Boyte and Kari were primarily interested in using public work to introduce youth to the craft of citizenship, local workforce officials in California are also finding that it is a powerful tool to teach occupational skills, as well as work readiness attitudes such as teamwork, customer service and reliability.

Youth workforce programs

To study the implementation of WIA-funded youth workforce development programs in California, a team of UC Davis and UC Cooperative Extension (UCCE) researchers partnered with the California Workforce Investment Board and the Employment Development Department between March 2005 and September 2006. The research team included three UCCE 4-H youth development advisors as well as UC Davis faculty and researchers with expertise in community development and public policy.

The purpose of this research was to investigate how WIA provisions for youth programs are being implemented in local workforce areas, to gain an understanding of what is working and what is not, and to make this information available to decision-makers, primarily at the state level. The research design, approved by state officials and an evaluation advisory committee of state agency representatives, emphasized case studies of local implementation using qualitative analysis techniques and methods.

A key goal was to identify patterns and trends in the service delivery motifs that local areas were employing, particularly those that local stakeholders viewed as successful or promising. Since WIA legislation grants local workforce areas considerable discretion to tailor programs to local needs and circumstances, state officials were interested in learning more about how local discretion was being exercised. Consistent with the "field network approach" used in many studies of public policy implementation (Nathan 2000), the final product was a detailed cross-case analysis comparing implementation across local workforce areas and identifying policy and programmatic recommendations (Lamming et al. 2006).

The findings reported here represent just one component of this larger youth workforce evaluation, which in turn was part of an even broader evaluation of the workforce development system in California based on more than 400 interviews, observations, review of documents and analysis of administrative data (Campbell et al. 2006).

Sample selection. California is divided into 50 local workforce areas, which comprise cities, counties or consortia of cities or counties (fig. 1). We selected 10 of these areas to maximize variation in location, economic conditions, size, administrative structure and conditions for youth (table 1). The 10 study areas were: (1) NoRTEC

Photos: Private Industry Council of Butte County/Checkers

Checkers, a popular Italian restaurant in Oroville, is Butte County's primary training program for out-of-school youth who are eligible for Workforce Investment Act assistance. *Left*, instructor Tim Yarbrough shows Monica Rodriguez how to prepare BBQ Italian ribs on an outdoor grill; *center*, the restaurant interior; *right*, Kristy Saechao prepares shrimp for seafood crespelle.

(Northern Rural Training and Employment Consortium, comprised of Del Norte, Lassen, Modoc, Plumas, Shasta, Siskiyou, Sutter, Tehama and Trinity counties); the counties of (2) Merced, (3) Orange, (4) San Joaquin, (5) Solano, (6) Sonoma and (7) Tulare; and the cities of (8) Los Angeles, (9) Santa Ana and (10) Glendale and Burbank (Verdugo Consortium). Collectively, these areas serve about one-third of the state's population and receive almost 30% of California's WIA allocations.

Case studies. Research team members prepared case studies of local WIA youth programs and the Youth Councils appointed to provide direction for these programs. Youth council members include representatives of youth-serving agencies, public housing authorities, parents of WIA-eligible youth, and others with interest or expertise in youth policy. Members are appointed by the local Workforce Investment Board in cooperation with local elected officials. We observed at least one Youth Council meeting in nine of the 10 workforce areas studied, reviewed documents such as Youth Council minutes and agendas, explored Youth Council and youth program Web sites, and developed profiles of each workforce area using data from local informants and official sources (such as U.S. Census data, city and county government statistics).

In addition, we typically interviewed eight to 12 key informants in each local workforce area, including: the lead Workforce Investment Board staff person for youth; the chair of the Youth Council; up to three members of the Youth Council, including at least one youth when possible; and representatives of at least two youth services providers that receive subcontracts from local Workforce Investment Boards.

Across the 10 local workforce areas studied, the research team conducted 104 confidential interviews between March 2005 and May 2006. Research team members followed a common interview protocol to ensure the comparability of responses, but were encouraged to adapt questions to learn as much as possible about unique individuals, situations and perspectives. Questions covered a wide range of topics, including the Youth Council's composition and scope of responsibilities, the nature of funded contractors and their services, the mechanisms in place to encourage collaboration among local youth-serving organizations, and the respondents' views on what had and had not worked well during local implementation of WIA youth provisions.

Qualitative analysis. All interviews were tape-recorded and transcribed. Making use of qualitative analysis software (QSR N6), we then performed a content analysis on the transcripts and field notes, looking for common themes, patterns and issues both within and across the 10 local workforce areas.

TABLE 1. Demographics of youth in case study areas

County/area	Total population (1/1/2005)	Youth up to age 17 (2005)	Child poverty rate (2002)	Out-of-school, out-of-work youth ages 16–19 (2000)	Youth meeting UC/CSU entrance requirements (2002–2004)
	..... *no.*		..... %		
Los Angeles*	10,166,417	2,779,941	25.3	10.7	36.3
Merced	241,464	77,825	26.2	12.0	22.0
NoRTEC†	606,555	110,818	20.0	9.2	27.9
Orange‡	3,047,054	800,650	14.2	7.6	36.0
San Joaquin	655,319	195,328	19.6	11.7	30.4
Solano	420,307	111,382	10.2	7.9	27.8
Sonoma	477,697	109,966	9.7	7.9	35.6
Tulare	411,701	131,883	32.1	12.4	23.8

* Includes Los Angeles and Verdugo Consortium (cities of Glendale and Burbank) local workforce areas.

† Figures represent totals or averages across nine NoRTEC counties: Del Norte, Lassen, Modoc, Plumas, Shasta, Siskiyou, Sutter, Tehama and Trinity.

‡ Includes Orange County local workforce area and City of Santa Ana.

Source: Total population figures from California Department of Finance (2006); remaining figures from Children Now (2005).

Photos: Geoff Will

▶ **In Tehama County, Workforce One members learn job skills in basic construction, home maintenance and landscaping. Earning minimum wage, they have done community-service jobs such as restoring parks and planting trees. *Top*, Corvin Johnston repairs a pipe. *Bottom*, Charlotte McNamara operates a drill press.**

Given the funding cuts and mandate to provide more holistic services, we were particularly interested in whether local areas were finding ways to leverage their limited resources through innovative programs or partnerships. All interviewees were asked to identify local programs, collaborations or initiatives that they considered highly successful. As our fieldwork progressed, we identified programs that had been nominated by multiple respondents. We then created program profiles by interviewing key staff and gathering perspectives from local observers not directly connected with the program.

In some local workforce areas, we were able to directly observe youth program activities and conduct focus groups with participating youths (table 2). We conducted eight focus groups with a total of 53 youth between October 2005 and April 2006. We questioned these youth about their aspirations for future employment, experience with WIA programs, exposure to vocational information in school, and sources of information about jobs. We then analyzed the notes and transcripts from the focus groups, finding that many youth had positive or even "life changing" experiences with WIA programs.

What works, and doesn't work

As we reviewed the data, it became clear that certain WIA-related innovations were relatively ineffective, while programs that engaged youth in public work were particularly promising. For example, while local Youth Councils serve as valuable networking bodies, in most local areas they have not lived up to the hope that they would spur new efficiencies by serving as a focal point for the integration of youth services. In fact, only slightly more than half of local area executive directors surveyed in 2006 indicated that they would even retain their Youth Council if WIA reauthorization no longer required it (Campbell et al. 2006).

Another disappointment concerning local implementation involved work readiness certificates, which are a way of credentialing youth as potential employees based on the expectations of the local business community. Despite the state-level attention this approach was receiving as a promising means of partnering with local businesses, we found that none of the case study areas with these certificates had managed to roll out a viable program. Impediments included the practical difficulty of informing and enlisting a sufficient number of employers and youth, as well as philosophical differences, such as how academic the standards should be, and whether the focus should be on WIA-eligible youth or all youth.

By contrast, in four of the 10 local workforce areas, we encountered lead youth program staff who were excited about public work projects. These programs evolved through local innovation rather than as a result of federal mandates, so not all local areas have tried them. The workforce areas that had launched such public work initiatives found that they provide youth with valuable work experience and consistent adult support, and have been able to extend the reach of limited workforce development dollars by leveraging funds from local public agencies or

TABLE 2. Focus group interview participants

Location*	Number	Gender	Race	Age (years)
Los Angeles/Watts	7	6 female 1 male	6 black 1 Latino	18–22
Los Angeles/Culver City	9	2 female 7 male	4 black 1 Latino 4 Asian	18–20
Merced County	11	10 female 1 male	8 Latino 2 Asian 1 white	18–23
NoRTEC (Butte County)	9	8 female 1 male	1 black 3 white 3 Latino 2 Asian/Pacific Islander	18–20
San Joaquin County	4	2 female 2 male	3 black 1 white	18–21
Solano County	4	3 female 1 male	3 black 1 Latino	18
Sonoma County	2	1 female 1 male	2 white	18 & 20
Tulare County	7	4 female 3 male	5 Latino/Hispanic 1 Asian 1 white	18–21
Totals	53	36 female 17 male	19 Latino 17 black 9 Asian/Pacific Islander 8 white	18–23

* No focus groups were held in Orange County, Santa Ana or Verdugo Consortium.

businesses. In addition, some of these public work initiatives have fee-for-service arrangements that can funnel income back into the program.

The particular foci or profiles of the public work projects that we studied varied (table 3), but nonetheless our analysis identified three key program elements: (1) a holistic approach that combines employment preparation with social services and personal support; (2) structures that group youth in cohorts where they work/learn together, combining paid work with the chance to build self-confidence and learn what it takes to be a good employee; and (3) caring adult supervision of significant duration that combines discipline and support in appropriate measures.

These program features, which go well beyond what was typically present in summer jobs programs offered under the Job Training Partnership Act (the federal predecessor to the WIA), are consistent with Mangum's (2000) literature review, which identified features associated with successful youth workforce programs: enrollment duration of at least 1 year; integrated combinations of basic education, skills training and on-the-job training; a visible connection to jobs of promise; mentoring by respected adults; opportunities for high-profile community service; possibilities for further educational advancement upon demonstrated success; and youth sharing in program decision-making responsibilities, allowing a sense of empowerment that is greater than that available through antisocial activities.

Although youth workforce programs often involve complex collaborations among a variety of government and nonprofit service providers, the exemplary cases that we identified tended to have discrete identities, cultures and program boundaries. For youth participants, joining one of these programs provided an identity that typically became a source of pride, similar to what other youth might experience by being part of a sports team, band, or even a gang.

TABLE 3. Youth public work programs studied

Local Workforce Investment Area	Program	Type of work experience	Lead service provider	Type of organization
Orange County	Conservation Corps	Work crews perform recycling and community improvement projects	Orange County Conservation Corps	Nonprofit
NoRTEC	Checkers	Team runs restaurant	Butte County Private Industry Council	Nonprofit
	Workforce One	Teams do community improvement projects	Tehama County Job Training Center	Nonprofit
Santa Ana	Taller San Jose	Apprenticeships in construction, medical and IT fields	Sisters of St. Joseph	Faith-related nonprofit
Verdugo Consortium	Summer Brush Clearance Program	Crews clean hillside brush for wildfire prevention	Glendale Youth Alliance	Nonprofit

Holistic, developmental approach

Successful public work programs typically featured a holistic, developmental approach, working with youth in age-appropriate ways and developing their skill sets patiently over time. Specific program elements included mentoring and employment-related counseling, but also services to help youth overcome barriers to success such as drug addiction, low self-esteem, unhealthy relationships, criminal histories and mental health problems. Most local service providers applauded the fact that the WIA's required elements gave them greater flexibility to use workforce funds to provide vital social services. "I don't think we would have ever funded something like drug counseling services before . . . [Now] we're not just resumes and applications; it's your mental health, and all that other stuff that's going along with it," said a Los Angeles area provider. Likewise another south-state provider emphasized why it is essential to first overcome barriers before reaching other goals: "How in the heck am I going to send a kid that's all screwed up on methamphetamines, or a girl that's being beat up by her boyfriend, to a job? We have to work on those barriers first."

An example of the holistic approach is the Glendale Youth Alliance, a primary youth services contractor for the Verdugo Consortium local workforce area. Glendale Youth Alliance is a nonprofit organization that was started when the community came together to address a nascent gang problem. They began by putting youth to work in supervised crews that cleared brush from hillsides as part of the city's wildfire prevention efforts. The alliance has since developed programs that give youth increasing experience and responsibility working in local government offices, nonprofits, hospitals and businesses. The alliance pays the youth's wages except in the most-skilled jobs, where their employers pay. As an additional incentive for businesses to participate, the City of Glendale underwrites the cost of workers' compensation.

The lure of employment is the initial draw for most youth, but in order to work they must be in school and maintain an acceptable grade point average, or be enrolled in a certificated program or vocational school. Each participant has a counselor/mentor that works with him or her on a personal basis. Glendale Youth Alliance staff see mentoring as a key component. "We don't just attack the work part. We attack the whole person because in any work environment, the whole person comes to work," a staff member said.

The holistic approach also is evident in Glendale Youth Alliance's Summer Brush Clearance Program for 14- and 15-year-olds. Before working in the hills clearing brush, these youth get 3 weeks of intense life and job skills training, 4 days a week, 4 hours a day. They also learn CPR and first aid, receive on-site tool training, and go on field trips such as to the Museum of Tolerance to learn about conflict resolution.

Group work experiences

A second element of successful youth public work programs was creating a structured experience with youth working in cohorts and staff working alongside them to ensure that they learn key work attitudes and skills.

Photos: Orange County Conservation Corps

An evaluation of workforce training programs for young people in California found that the most successful ones offer: a holistic approach that integrates social services with on-the-job training; the opportunity to work closely with a group; and a balance of discipline and support from adult mentors. *Top*, Orange County Conservation Corps members work at Bolsa Chica Ecological Reserve; *inset*, OCCC members Rocio Rodriguez (left) and Olivia O'Neal.

In some cases, these projects generated funds that are funneled back to support the program, as illustrated by Checkers restaurant in Butte County and Workforce One in Tehama County, both part of the NoRTEC.

Checkers restaurant. Checkers is a popular restaurant in Oroville that serves elegant Italian food. It is also Butte County's primary program for WIA-eligible, out-of-school youth, though its patrons might never guess that it was started specifically for that purpose. When it opened in 2001, the idea was to introduce WIA-enrolled youth to the world of work in what the program director hoped would become a self-sustaining business enterprise. Checkers has surpassed all expectations, offering work experience and a character-building program for 18- to 21-year-olds, while generating an annual six-figure income that helps support this and other programs. Checkers is branching out, doing catering for large social affairs and gaining even more positive publicity and revenue.

The 18 youth participants are paid minimum wage as they take on all the jobs in the restaurant, from greeting to cooking to serving to cleaning up. While performing the various jobs, they learn about customer service and how to present themselves as employees. They also are required to pass the state sanitation course. The program is designed to give each participant 1,000 hours of experience, and one of the most difficult administrative duties is getting the kids to leave the program when it is time for them to do so.

Workforce One. Workforce One is a crew of older youth (ages 18–21) with one supervisor assigned to five participants. The supervisors function as boss, trainer, mentor, coach, parent, counselor and drill sergeant as the crews perform a variety of general labor, maintenance and groundskeeping jobs. Crew members acquire job skills including basic construction and repairs, painting, plumbing, electrical, horticulture, use of tools and safety; they are also taught the behaviors, attitudes and responses that employers expect. They receive minimum wage and are expected to meet work standards for productivity, quality, attendance and following instructions. Work-related mistakes and "soft skill" problems (such as communication issues, relationship problems) are approached as learning opportunities, but participants who do not respond to instruction and warnings must then face the real-world consequences of being suspended or fired.

The value of a caring, continuous adult relationship to a young person cannot be overestimated.

Originally, Workforce One performed community-service work only, such as refinishing and painting the city pool, planting trees as part of a downtown beautification effort, and rebuilding the dugouts, fences and restrooms at the Little League ballpark. An unexpected outcome was the sense of accomplishment and civic pride that the youth experienced as they saw the fruits of their labor, and as they received accolades from city councils, county department heads and community leaders (Boyte 2004).

As the reputation of Workforce One grew, requests for their assistance started coming in from private-sector businesses and homeowners struggling to find trustworthy day laborers. Filling this niche, Workforce One regularly does minor sprinkler and fence repair, pruning and planting, painting and simple building repairs. Although crews continue to provide community-service work at no charge, word-of-mouth brings in a steady stream of paying customers. After one year, Workforce One was generating enough revenue to cover the wages and payroll costs for a crew of five full-time workers.

Discipline and support

A number of the youth workforce program leaders we interviewed emphasized that a healthy balance of discipline and support is structured into their programs. For example, a staff member at Glendale Youth Alliance described his summer brush-clearing program as a "boot camp" that also provides the positive group experience that teens crave: "It's very fun, though it's very rigid. There is a hard start time and if you miss it three times, you're out. [But we also] have 'Team of the Week' and 'Worker of the Week.'"

Another example of a program featuring discipline and support is the Orange County Conservation Corps, an Anaheim-based, countywide nonprofit organization with a $3.5 million annual

budget. The Corps features a structured experience in which youth do recycling and other community improvement projects. Youth work in crews with supervisors, wear uniforms and are transported in Corps vans.

Corps members maintain a highly structured 40-hour week, with 32 hours of work and 8 hours of school. Nearly 90% lack a high school credential and attend the Corps-run charter high school. The rest receive pre-employment and other skills training. They are paid between minimum wage and $9.50 per hour, and are eligible for better jobs in the Corps and higher pay if they do well. However, Corps participants are dismissed if they step out of line too many times, although they are allowed one second chance to return to the program. A Corps representative said: "We take a very employer-like approach. They get monthly evaluations. They can get merit raises, but there is nothing automatic."

Relationships with WIA-funded staff give youth the opportunity to grow and develop. Because the approach emphasizes long-term nurture as opposed to episodic encounters, these relationships can last for months or even years. The value of caring, continuous adult relationships to young people cannot be overestimated, particularly if relationships with their parents are problematic.

Benefits to youth and society

The WIA provision for a comprehensive approach to youth development has led local workforce officials to increase the variety and depth of youth services. But because the mandate for increased quality of service has not been supported by a corresponding increase in funding, fewer youth can benefit from WIA programs. The answer, as many previous studies have concluded, is not to shortchange the quality of services, but rather to increase the public investment in workforce programs (Giloth 2004; Mangum 2000; Reich 1991).

Our review of youth workforce programs found that public work projects are particularly promising. These efforts incorporate many features associated with successful program outcomes. They inspire high levels of commitment from both participating youth and workforce staff, create tangible public benefits such as fire protection and clean parks, and attract additional financial resources that leverage limited funding.

It is important to keep in mind that no single approach can satisfy the needs of California's diverse youth population. Public work projects are especially successful for youth who are willing and able to make a long-term commitment. However, these projects are less appealing to youth who want or need immediate employment. This is one of many reasons why local workforce officials still view short-term summer jobs programs as a necessary component of their overall efforts, despite their limitations as a tool for youth workforce development.

Every youth that the WIA system can put on the path to secure employment is a youth less likely to burden the state later with social services or prison expenses. However, the rationale for these programs is much broader. By teaching discipline, responsibility and work-related skills, exemplary youth public work programs contribute to the vital national challenge of mobilizing the skills of all our citizens, beginning with our most valuable potential asset — our young people.

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2007 Index

The following peer-reviewed research articles, and news and editorial coverage, were published in *California Agriculture*, Volume 61, Numbers 1 to 4 (January-March, April-June, July-September, October-December), 2007. Back issues are $5 per copy, while supplies last. To subscribe to the journal, order back issues, search the archives or download PDFs of all research articles in full, go to: http://CaliforniaAgriculture.ucop.edu.

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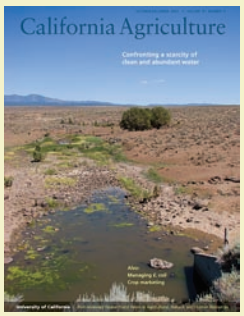

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Research articles

Animal, avian, aquaculture and veterinary sciences

Berentsen AR, Timm RM, Schmidt RH. The Coyote Lure Operative Device revisited: A fresh look at an old idea. Cal Ag 61(1):20–3.

Castillo AR, Santos JEP, Tabone TJ. Mineral balances, including in drinking water, estimated for Merced County dairy herds. Cal Ag 61(2):90–5.

Economics and public policy

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Food and nutrition

Cena ER, Joy AB, Heneman K, Zidenberg-Cherr S. Low-income women in California may be at risk of inadequate folate intake. Cal Ag 61(2):85–9.

Crawford PB, Lamp CL, Nicholson Y, et al. Food insecurity may be linked to childhood obesity in low-income Mexican-American families. Cal Ag 61(3):106–11. OB

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Kirkpatrick N, Briggs M, Zidenberg-Cherr S. California teachers support the Nutrition Competencies — new nutrition instruction guidelines. Cal Ag 61(1):40–6.

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Human and community development

Billikopf G. Quality evaluations should not be taken for granted. Cal Ag 61(1):35–9.

Espinosa-Hall GB, Metz D, Johns M, et al. UCCE helps community coalitions reduce childhood overweight. Cal Ag 61(3):124–30. OB

Land, air and water sciences

Knox AK, Tate KW, Dahlgren RA, Atwill ER. Management reduces *E. coli* in irrigated pasture runoff. Cal Ag 61(4):159–65.

Kuhn TJ, Tate KW, Cao D, George MR. Juniper removal may not increase overall Klamath River Basin water yields. Cal Ag 61(4):166–71.

Lubell M, Fulton A. Local diffusion networks act as pathways to sustainable agriculture in the Sacramento River Valley. Cal Ag 61(3):131–7.

Natural resources

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Phillips RL, McDougald NK, Atwill ER, McCreary D. Exclosure size affects young blue oak seedling growth. Cal Ag 61(1):16–9.

Phillips RL, McDougald NK, McCreary D, Atwill ER. Blue oak seedling age influences growth and mortality. Cal Ag 61(1):11–5.

Pest management

Brodt SB, Goodell PB, Krebill-Prather RL, Vargas RN. California cotton growers utilize integrated pest management. Cal Ag 61(1):24–30.

Casey C, Newman J, Robb K, et al. IPM program successful in California greenhouse cut roses. Cal Ag 61(2):71–8.

Shrestha A, Hembree KJ, Va N. Growth stage influences level of resistance in glyphosate-resistant horseweed. Cal Ag 61(2):67–70. BT

Plant sciences

Kahn TL, Bier OJ, Beaver RJ. New late-season navel orange varieties evaluated for quality characteristics. Cal Ag 61(3):138–43.

Lopez G, Johnson RS, DeJong TM. High spring temperatures decrease peach fruit size. Cal Ag 61(1):31–4.

Marvier M. Pharmaceutical crops have a mixed outlook in California. Cal Ag 61(2):59–66. BT

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Feenstra G, Tomich T. Sustainable food systems link growers to new consumer markets in California. Cal Ag 61(4):146.

Gillespie J. Lessons from the *E. coli* outbreak — understanding the complexity of foodborne disease. Cal Ag 61(2):50.

Gomes WR. Taking the University to the people. Cal Ag 61(1):2.

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Key to 2007 special sections

BT = Biotech risks and benefits

OB = Examining obesity

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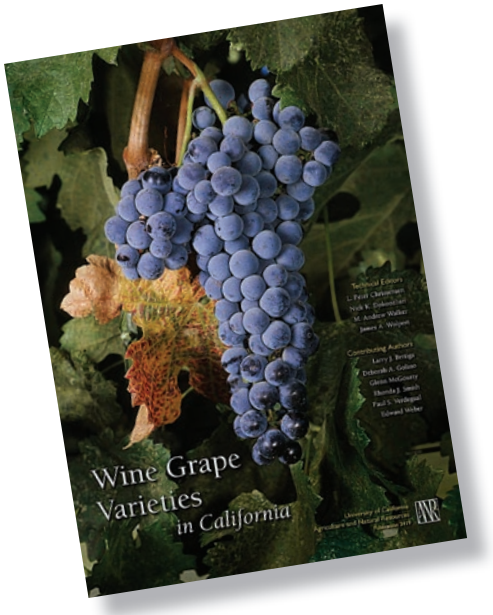

Wine Grape Varieties in California

Growers, vintners and wine enthusiasts will appreciate this definitive guide to 36 major wine-grape varieties grown in California. The book covers wine-grape sources; physical characteristics such as clusters, berries and leaves; harvest periods and methods; and winery use. It is beautifully illustrated with lush, close-up color photographs by Jack Kelly Clark of each variety's clusters, leaves and leaf shoots. Additional information includes ripening periods and dates, vine and rootstock selection, trellis selection and management, detailed illustrations of grapevine structure, a glossary and bibliography. *ANR Pub 3419, 2003, 188 pp., $30*

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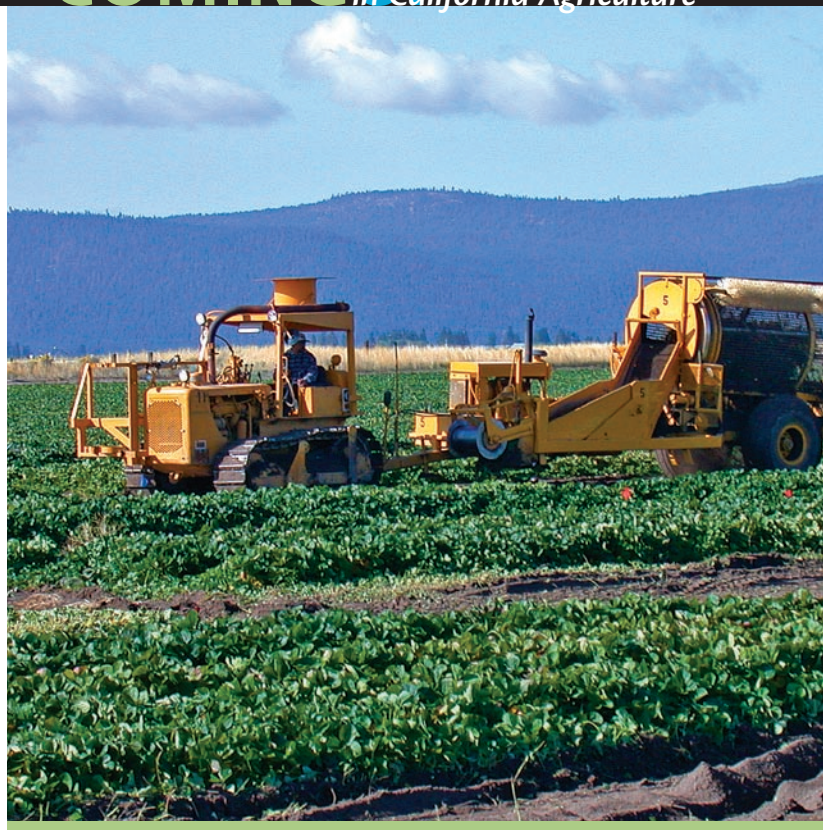

Methyl bromide alternatives for strawberry nurseries

Methyl bromide is a fumigant applied to the soil before planting for season-long control of soilborne pathogens, insects, nematodes and weeds. While effective, methyl bromide is currently being phased out due to its impacts on stratospheric ozone. This presents a major challenge for strawberry nursery producers in California, who heavily rely on this fumigant for soil sterilization. In the next issue of *California Agriculture*, UC researchers evaluate the effectiveness of alternative fumigants, as well as production costs, following nursery stock through the low- and high-elevation phases of runner-plant propagation and a complete cycle of fruit production in coastal fields.

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