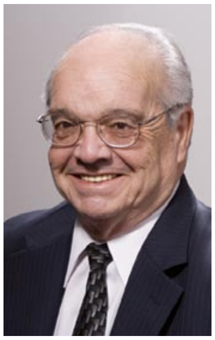
JANUARY-MARCH 2007 • VOLUME 61 NUMBER 1

California Agriculture

Old oaks, new life:
Stemming woodland loss



W.R. Gomes
Vice President, Agriculture and Natural Resources

Taking the university to the people

January is named after the Roman God Janus — the keeper of gates, the God of beginnings. Janus is depicted in Roman culture as simultaneously looking forward and backward, for each beginning is based on developments of the past.

When I arrived at UC in 1995, UC President Jack Peltason asked me to develop a mission statement for ANR, to examine the administrative structure of the organization, and to plan for the new millennium. As I retire in 2007, UC President Robert Dynes has asked me to reflect upon the changes that have occurred and to summarize the few that give me the greatest source of pride. Because this January marks my last editorial before retirement, I'd like to share my responses with you.

I'm proud of the cultural changes that have taken place in our division. Driven by a need to serve a rapidly changing industry in a rapidly changing state, we now emphasize emerging issues in agriculture, natural resources and human sciences and position ourselves to address these needs. While we continue to serve broadly based stakeholders, we no longer focus on discipline-oriented and geographically defined goals. Rather, our decisions and directions are designed to address those areas where we can make the greatest difference.

To effect this change, we started with a strategic plan — based on a mission, articulated by a vision and tempered by core values that ANR as a unit enumerated. The plan was developed with input from a wide range of sources and reflection from many thoughtful people. Designed to be dynamic, it outlined criteria for determining program priorities that could serve as the basis for virtually all future decisions; the plan was not a road map, but a compass.

In the current climate of change and quest for adherence to the highest and strictest standards, it is gratifying to note that we — as an organization — embraced ethical behavior as the first of our core values.

From our planning process came a set of strategic assumptions, mid- and long-term program priorities, and an in-depth look at our organizational structure. At the urging of many of our stakeholders, we developed a new structure that emphasized divisionwide planning, installed program leaders and rejuvenated workgroups, among other changes designed to emphasize opportunities and address issues.

To help position our programs for 21st-century California, we asked distinguished UC scientists to think about the long-term future (the next 25 years) of California's agricultural, natural and human resources for special editions of *California Agriculture* to be published in the millennial year. The four-part collection — on population, resources, food production and food security — (Vol. 54, Nos. 1, 2, 4 and 5) continues to provide a strong basis for our thinking.

I'm proud of our people. My 11 years at UC have been a rich time of working with a cadre of gifted academics, dedicated staff and insightful administrators.

During the later 1990s, we began developing plans for the renewal of our programs that had been decimated by the budget cuts of the early 1990s. Our people looked forward: rather than trying to reclaim lost "turf," they anticipated new opportunities and directions. The cooperative atmosphere was inspiring.

When the budgetary axe fell again a few years later, we were subjected to all of the negatives: program closures, layoffs, frozen positions, redirection of carefully saved funds. But, overall, we retained our perspective, embraced our priority-planning process, minimized our hand-wringing and finger-pointing, and responded positively to adversity. This is a tribute to all of our people on the campuses, in the counties, and in ANR offices based in Oakland, Davis, Kearney and Riverside.

I'm proud of the increased visibility that our people and programs have gained in the system, on the campuses and with the public. With the cooperation of UC Presidents Richard Atkinson and Robert Dynes, we demonstrated to them and others many of the important programs that the University conducts throughout the state. After members of the UC Board of Regents walked through the lettuce fields and packing plants of the Salinas Valley, they better understood the issues surrounding *Escherichia coli* and Salmonella outbreaks; after viewing the limited damage of Pierce's disease in the Napa Valley, they could address the devastation later wrought by the appearance of the glassy-winged sharpshooter.

When President Dynes introduced his concept of "Research-Development-Delivery" to the university community, we were able not only to demonstrate "R, D & D" in action, but also a system of delivery that is unparalleled.

As UC wrestles with issues of diversity, we are able to showcase nutrition, after-school and youth programs that reach African-American, Latino, Hmong, Vietnamese and other underserved populations. Legislators from Sacramento and Washington and visitors from around the world have been able to see that we truly take the university to the people — all of the people.

President Atkinson expanded the dialogue with our stakeholders by establishing the UC President's Advisory Commission on Agriculture and Natural Resources. Both he and President Dynes have worked hand-in-hand with California leaders to identify the issues, foresee the direction of California's resources and define the University's role in addressing them. The relationship between the University and the industry is strong.

I'm proud to have served UC. Several of you have asked what I will be doing after retirement. I might go fishing. Anne and I will travel and spend time with our children and extended families. I don't know how much — or how little — I'll be involved in ANR issues, but a part of my heart will always be with the University of California.

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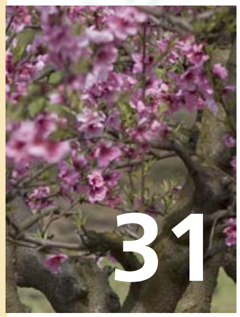

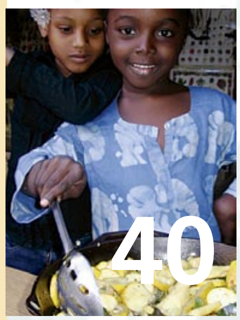

News departments

Taking the University to the People — an oral history project

In honor of Vice President Gomes' retirement, UC President Robert Dynes in October 2006 announced "Taking the University to the People," a UC Cooperative Extension oral history project. The oral history will provide a living record of the individual contributions of UCCE advisors, specialists and staff, and examples of the positive impact of the UC-industry research, development and delivery continuum. This project is expected to take 5 years and include about 100 interviews. Its estimated $400,000 cost will be raised from industry and private donations. For more information, contact Cindy Arnot Barber, (510) 987-9139 or cynthia.barber@ucop.edu.

Letters

WHAT DO YOU THINK?

The editorial staff of *California Agriculture* welcomes your letters, comments and suggestions. Please write to us at calag@ucop.edu or 1111 Franklin St., 6th floor, Oakland, CA 94607. Include your full name and address. Letters may be edited for space and clarity.

When transgenes wander, he worries

Re: Norman Ellstrand's "When crop transgenes wander in California, should we worry?" (July-September 2006).

How many superweeds in our fields and pastures owe their existence to hybridization? We forget that the parent species of hybridized plants share common pathways of molecular evolution, and therefore "like" chemistries; the parent species have a much higher probability of evolving into the traited hybrid on their own, without human tampering.

Hybrids bring twigs on the tree of evolution together, under an umbrella of common plant chemistries, whereas genetic engineering will join the twig of one limb to the twig of another limb or to the limb itself, with a potential for radical new plant chemistries such that the definition of a species, namely the interbreeding of individuals, is challenged.

We don't have to pretend that we do transgenic modifications for the good of mankind when money is the goal, and we don't have to subject Mother Earth to experiments without an assured endpoint. Are we going to create a transgenic world by default? Perhaps we should consider inoculating another planet in the galaxy with the experiments of our transgenic tinkerings, and not be so readily willing to sacrifice our own and only life space to transgenic modifications.

Bud Hoekstra
Berry Blest Farm
San Andreas

Asian students appreciate journals

Editor's note: California Agriculture *recently donated 12 boxes of journals, including* Science, Scientific American *and* California Agriculture, *to Bridge to Asia (BTA). Since its founding in 1987, BTA has collected and shipped more than 5 million books and periodicals to 1,000 universities in China, Vietnam and Cambodia.*

Thank you for the journal and book donations from your publication. The journals are a valuable collection and are certain to be greatly appreciated and well used by students and teachers in Asia.

Our collection efforts are ongoing, and we welcome you to share your interest in Asia's need for books and journals with friends and colleagues who may wish to help.

Newton Liu, Vice President
Bridge to Asia (www.bridge.org)

Correction

A formula was incorrect in "Cost benefit analysis conducted for nutrition education in California" (October-December 2006), on page 189 in both the "Calculation of direct benefits" box and table 2 footnote. The correct formula is:

$$A \times B \times C \times D = E$$

$$E \times F = \text{Benefits}$$

The authors (Joy and Goldman) regret the error.

UNIVERSITY of CALIFORNIA

California Agriculture

Peer-reviewed research and news published by the Division of Agriculture and Natural Resources, University of California

VOLUME 61, NUMBER 1

Executive editor: Janet White
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California Agriculture (ISSN 0008-0845) is published quarterly and mailed at periodicals postage rates at Oakland, CA, and additional mailing offices. Postmaster: Send change of address "Form 3579" to *California Agriculture* at the above address.

RATES: Subscriptions free upon request in U.S.; $24/year outside the U.S. After publication, the single copy price is $5.00. Orders must include payment by check or international money order in U.S. funds, payable to UC Regents. MasterCard/Visa accepted; requests require signature and card expiration date. Please include complete address. For online ordering, go to http://CaliforniaAgriculture.ucop.edu.

Trevor Suslow

A joint UC Davis/USDA research project will sample crops in the Salinas Valley, as well as animal droppings and water. Genetic tests will be used to "fingerprint" and track bacterial contaminants such as *E. coli* O157:H7.

Expanded research to target E. coli *outbreaks*

UC and federal scientists have proposed ramping up a long-planned study of *E. coli* in Monterey County to include areas of San Benito County where spinach implicated in the September 2006 *E. coli* outbreak might have been grown.

By January, the team will begin collecting thousands of samples of domestic animal and wildlife droppings; creek, ditch and irrigation water; and soil and lettuce from farms. The investigators are now hammering out the details of a proposal to expand the research effort by about 50%, encompassing the larger territory.

The original 4-year study was funded in October 2006 with a $1.17 million research grant from the USDA-Cooperative State Research, Education and Extension Service. When the funding was first requested, the focus was on a series of *E. coli* outbreaks from 1995 to 2005 across the nation, seven associated with farms in the Salinas Valley. Fifteen outbreaks were related to lettuce (see page 6) and one to spinach. However, the late September 2006 spinach outbreak captured national headlines and increased calls for research to prevent future *E. coli* crises.

In the September 2006 outbreak, 204 cases of illness due to *E. coli* O157:H7 in spinach were reported to the U.S. Centers for Disease Control and Prevention (CDC), including three deaths and 102 hospitalizations. Food safety experts estimate that only one of 20 such illnesses is reported to the CDC; the actual number of people sickened in this outbreak was more likely about 4,000. (*E. coli* O157:H7 is one of many illnesses monitored by the CDC; see table.)

The economic impact on spinach growers has been tremendous. The United Fresh Produce Association estimated that losses to processors alone reached $50 million to $100 million. That does not include losses to growers or retailers of spinach or other fresh-cut products.

Although the source of the *E. coli* O157:H7 that contaminated spinach and the exact farm where the spinach was contaminated have not yet been confirmed, the California Department of Health Services (DHS) has investigated four farms and ranches in San Benito and Monterey counties. During a press conference call on Oct. 26, 2006, Kevin Reilly of DHS confirmed that *E. coli* O157:H7 isolates found in wild pig feces, the feces of several cows, and in a stream on one of the four farms were genetically identical to the strain that caused the deaths and serious illnesses related to spinach. Although the specific mechanism of contamination remains unknown, wild pigs could explain how *E. coli* O157:H7 spread from cattle on the ranch to the spinach field, which was just under a mile away, Reilly said. The pigs could have tracked the bacteria into the field or spread it through their droppings.

The news was of great interest to Edward (Rob) Atwill, UC Davis School of Veterinary Medicine professor and co-principal investigator of the newly funded study; and principal investigator Robert Mandrell, research leader of the USDA-Agricultural Research Service Produce Safety and Microbiology

Selected categories of foodborne-disease outbreaks, cases and deaths in the United States, 1998–2002*

	Outbreaks	Cases	Deaths
Bacterial			
Campylobacter	61	1,440	0
Clostridium perfringens	130	6,724	4
Escherichia coli	140	4,854	4
Listeria monocytogenes	11	256	38
Salmonella	585	16,821	20
Shigella	67	3,677	1
Staphylococcus aureus	101	2,766	2
Vibrio parahemolyticus	25	613	0
Other	65	736	1
Total	1,185	37,887	70
Parasitic			
Cryptosporidium parvum	4	139	0
Cyclospora cayetanensis	9	325	0
Giardia intestinalis	3	119	0
Other	7	47	0
Total	23	630	0
Viral			
Hepatitis A	50	981	4
Norovirus	657	27,171	1
Other	2	122	0
Total	709	28,274	5
Total (including unlisted items) †	**6,647**	**128,370**	**88**

* The source of this data is the U.S. Centers for Disease Control and Prevention, MMWR Surveillance Summaries.

† Columns do not add up because totals also include 59,389 cases of disease with unknown origin, 1,060 cases of disease with multiple origins as well as 1,140 cases of disease caused by chemical toxins, none of which are listed here.

Research Unit. "The pigs are interesting to us now based on what we know about them, but we need to deal with facts," Mandrell says. "Wild pigs and other animals have to be studied more extensively to determine where the bacteria really are residing."

Scientists will carefully analyze the findings to identify which vertebrates are sources of *E. coli* O157:H7; assess the climate, landscape attributes and irrigation practices; and determine whether contaminated produce is associated with certain farming practices or environmental factors.

The researchers will use two sophisticated tests — MultiLocus Variable tandem repeat Analysis (MLVA) and Pulsed Field Gel Electrophoresis (PFGE) — to "fingerprint" and track bacteria. PFGE is the same process used by the CDC to discover whether strains responsible for human illnesses — and potentially associated with foodborne disease outbreaks — are related to one another, as was true in the case of spinach in September 2006. MLVA is a method for determining the genetic similarities among strains, allowing scientists to better understand how strains are related.

"Most strains of *E. coli* O157:H7 bacteria are so similar that we need to look at the genome to accurately trace the sources and transport of strains through the environment," Mandrell says.

Ultimately the scientists hope to tease out links between management practices, environmental conditions and vertebrates that carry the deadly bacteria. And then, the researchers will develop intervention strategies that sever the links.

More than three-quarters of California's total production of salad greens comes from the Monterey County region, including the majority of the lettuce produced for the U.S. market, which is valued at $1.3 billion annually.

— Jeannette Warnert and Editors

E. Lee Fitzhugh/UC Davis

Following the September 2006 outbreak of foodborne illness linked to *E. coli* O157:H7 in fresh spinach, state health investigators speculated that wild pigs may have transported the pathogen from infected cattle into fields.

Scientists test for *E. coli* O157:H7 in Salinas Valley

For the last 5 years, UC researchers conducting on-farm tests of lettuce, soil, irrigation water and runoff in the Salinas Valley did not detect any of the virulent *E. coli* O157:H7 bacteria that caused the September 2006 spinach outbreak.

UC Davis postharvest specialist Trevor Suslow and Monterey County farm advisor Steve Koike conducted hundreds of tests. "We have demonstrated that populations of nonpathogenic *E. coli* on lettuce in the majority of fields is very low," Suslow says. "To this date, we have never encountered detectable levels of viable, pathogenic *E. coli* using methods of high sensitivity and specificity."

Trevor Suslow

Hundreds of tests conducted in Salinas Valley lettuce fields did not detect any *E. coli* O157:H7.

However, since 1995, more than 15 illness outbreaks have been associated with lettuce or spinach consumption in the United States and Canada — and several have been traced to the Salinas Valley.

"We know that detectable levels of pathogenic *E. coli* have been found outside the farm, for instance in watersheds and drainage creeks — water sources that are not used for irrigation," Suslow says. "*E. coli* O157:H7 clearly occurs in the natural environment, and there are natural events such as wild animal movements or flooding that could introduce these pathogens to farmed land. The challenge is to learn whether and how they may survive, and develop management practices that protect food production areas from contamination."

In evaluating various *E. coli* O157:H7 detection methods, the researchers also found that several commercially available rapid-detection testing kits routinely gave "false positive" results. "An incorrect interpretation of results from these end-point tests could cause growers a lot of problems," Koike says.

The study, funded by the California Lettuce Research Board, has helped the scientists develop baseline microbiological indicator data for irrigation water, soil survival and lettuce, and has led to better understanding of the variability among fields and common crop production practices, Koike says. *— Editors*

OAKS

Research and outreach to prevent woodland loss

The UC Integrated Hardwood Range Management Program (IHRMP) was born 20 years ago out of controversy over managing California's 10 million acres of oak woodlands. Back then, major concerns included poor oak regeneration and ongoing woodland losses. "The question was, what to do about it?" says IHRMP director James Bartolome, a UC Berkeley range ecologist. "State regulation or research and outreach?" The California legislature opted for the latter and established the IHRMP in October 1986.

ANR Communication Services

Oak woodlands provide critical habitat for California native species, including 2,000 plants, 5,000 insects, 160 birds and 80 mammals. *Above*, a mule deer feeds on seedlings and other plants.

IHRMP is a collaboration among UC, the California Department of Forestry and Fire Protection, and the California Department of Fish and Game. "The program encourages stewardship of oak woodlands as functioning ecosystems," says former IHRMP manager Rick Standiford, now ANR associate vice president.

Oak woodland losses

While poor regeneration is no longer the pressing concern it was when IHRMP was established, the loss of oak woodlands is a bigger concern than ever. More than four-fifths of California's oak woodlands are privately owned, and with today's rising land values they can be worth far more when used for intensive agriculture or housing than for rangeland. Along the Central Coast, for example, oak woodlands are up to 10 times more profitable when planted in wine grapes and 100 times more profitable when developed for housing. According to a 2001 estimate, more than 30,000 acres of oak woodlands are now converted each year, up steeply from the mid-1980s to mid-1990s when losses were estimated at 60,000 acres for the entire decade.

IHRMP research has demonstrated the ecological impact of oak woodland conversions. Clearing the land for grapes, particularly on steep hillsides, can degrade water quality. And subdividing large parcels into ranchettes and housing developments degrades wildlife habitat. For example, in Sonoma County, there are more nonnative plants and fewer native birds in 10-to-40-acre ranchettes than in large parcels, according to a 1998 study led by Adina Merenlender of the UC Hopland Research and Extension Center. Ranchettes are increasingly popular around the state; in Nevada County, the average parcel size shrank from 550 acres in 1957 to just nine acres in 2001.

To share these findings with landowners, IHRMP offers workshops and publications such as the

Jack Kelly Clark

Moss and ferns cover an oak at the UC Hopland Research and Extension Center.

180-page *Guidelines for Managing California's Hardwood Rangelands*, which covers how to keep oak woodlands both protected and profitable. "Many large landowners want to do the right thing, but they need information and help," says former IHRMP director Douglas McCreary.

This is borne out by surveys of workshop participants. "Their management strategies have incorporated the importance of oak woodland habitat and riparian zones," ANR's Standiford says.

California native oaks

California has 19 native oaks ranging from the huckleberry oak, a mountain shrub that reaches only a few feet tall, to the valley oak, which may be the largest in North America with trunks up to 7 feet across and canopies up to 100 feet tall. Oaks are divided in three groups: the white group has light wood and rounded leaves or lobes, and includes valley and blue oaks; the red group has reddish-brown wood and leaves with spines or bristles, and includes coast live and California black oaks; and the intermediate group has a mix of these characteristics, and includes huckleberry and canyon live oaks.

The state of California defines oak woodlands as areas with more more than 10% oak canopy cover, and identifies eight oak woodland regions, with the largest regions in the Sierra Nevada foothills at 2.1 million acres, and along the North and Central coasts at 2.1 and 1.9 million acres, respectively. Both the oak species and their threats vary by region. For example, in the Sierra Nevada foothills, the dominant species include blue, black and interior live oak, and the threats include conversion to vineyards and ranchettes. In the Central Coast, the dominant species include valley, blue and coast live oak, and the threats include conversion to intensive agriculture and sudden oak death (see page 9).

IHRMP research has increased our understanding of the ecological value of oak woodlands, McCreary says. These habitats are among the most critical for California's native species, including some 2,000 plants as well as 5,000 insects, 80 amphibians and reptiles, 160 birds and 80 mammals. Oak woodlands are also key to water quality. As snowmelt flows down watersheds and into streams and rivers, oaks keep the soil in place to prevent erosion and stream sedimentation.

"Oak woodlands are often taken for granted but they need to be managed and conserved," says McCreary, an oak regeneration expert at the UC Sierra Foothill Research and Extension Center in Browns Valley.

Exclosures protect saplings

Poor regeneration is most common in three white oaks (blue, valley and Englemann) found mostly in the foothills of the Sierra Nevada, coast ranges and transverse ranges, which extend from Santa Barbara to the Mojave Desert. Typically, areas with poor regeneration have seedlings and mature trees but few saplings, which means most of the mature trees will not be replaced naturally when they die. IHRMP researchers have helped figure out why these young oaks are in trouble. Oaks are most susceptible during the transition from seedling to sapling, and the main threats include overgrazing by cattle and deer, and competition from the nonnative annual grasses that have replaced native perennial grasses.

IHRMP researchers have also helped figure out how to help more young oaks survive these threats. "We led the effort to develop artificial regeneration techniques," McCreary says. Successful approaches include controlling weeds and protecting seedlings from herbivores with shelters. The work is ongoing, with retired UC livestock advisor Ralph Phillips and colleagues recently showing that older blue oak seedlings are far more likely to survive than those that have just sprouted and that blue oak seedlings grow better in 2- or 4-foot "exclosures" (see pages 11 and 16).

To help landowners and managers restore oak woodlands, McCreary wrote *Regenerating Rangeland Oaks in California*. This 62-page guidebook includes step-by-step instructions on everything from transplanting seedlings to protecting them. "It's the only 'how-to' manual there is," he says.

IHRMP also organizes symposia every few years that cover the latest research on California's oaks. The sixth and most recent California Oak Symposium was held in Rohnert Park from Oct. 9 to 12, 2006, and

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Distribution of oak woodlands and forests in California (shaded area). Source: Allen-Diaz B, Standiford R, Jackson RD. 2007 (in press). In: *Terrestrial Vegetation of California.* Berkeley, CA: UC Press.

UC Natural Reserve System

California's 10 million acres of oak woodlands are threatened primarily by land conversions to intensive agriculture and housing, and poor regeneration. Researchers can study oak habitat at the UC Natural Reserve System's Stebbins Cold Canyon Reserve in Solano and Napa counties.

Yana Valachovic

A controlled fire in Humboldt County helps remove contaminated leaf litter.

Treatments could slow spread of sudden oak death

UC Cooperative Extension (UCCE) researchers are now testing new treatments that may help keep sudden oak death from spreading. First detected in California in 1995, the pathogen (*Phytophthora ramorum*) that causes this disease now infests 14 coastal counties and has killed more than a million native oaks and tanoaks. While experts acknowledge that there is little chance of eradicating sudden oak death where it is well established, there is still hope for stopping new infestations.

"We have to learn to live with this disease," says project leader Yana Valachovic, UCCE forest advisor for Humboldt and Del Norte counties. "Our goals are strategic containment and developing long-term management options for landowners." Her collaborators include the USDA Forest Service, California State Parks and the California Department of Forestry and Fire Protection.

In early 2006, the team began testing treatments in four forested areas totalling 140 acres in Humboldt County, the state's northern limit of sudden oak death. The treatments include:

- Cutting infected tanoaks and bay laurels, which are the species most likely to spread the disease, and burning the infectious twigs and leaves on-site.
- Using herbicides to prevent cut trees from resprouting as well as to kill infected trees.
- Treating healthy oaks with the fungicide Agri-Fos, which can protect against infection.
- Using controlled fire to consume infected leaf litter and other plant material on the ground.

To find the best combination of treatments, the team will evaluate them over a number of years. The evaluation measures include whether the pathogen appears in new vegetation such as seedlings and sprouts from cut trees, how much the treatments cost and public attitudes toward them. Valachovic will present the team's initial results in March 2007 at the Third Sudden Oak Death Science Symposium (http://nature.berkeley.edu/comtf/sodsymposium), which is sponsored in part by the UC Integrated Hardwood Range Management Program.

— Robin Meadows

Jack Kelly Clark

Simple protections, such as fencing and plastic treeshelters (shown at the UC Sierra Foothill Research and Extension Center), can improve the survival of oak seedlings in areas heavily grazed by cattle and deer.

— continued from page 8

featured sessions on issues from tree health to oak woodland stewardship and planning.

Conservation is key

While California is losing more acres of oak woodlands now than before IHRMP was established, the state is also conserving more acres. To facilitate oak woodland preservation, IHRMP helps local jurisdictions implement conservation easements. These typically limit development while allowing grazing and other sustainable uses, and give landowners financial benefits such as lower property taxes. "Land values have gone up so much. We need financial incentives for landowners to provide the public with services like watersheds and wildlife habitat," Standiford says. State funding sources for conservation easements include the 2001 Oak Woodland Conservation Act (AB 242), and IHRMP worked on the guidelines for dispensing funds as well as on the local Oak Management Plans required to secure them.

Most recently, IHRMP has shifted its outreach focus to land planners and policymakers. This is because oak woodlands are now regulated by various jurisdictions. "Many cities and counties have adopted ordinances and we help people meet these requirements," program director Bartolome says. At the state level, the 2004 Oak Woodlands Conservation: Environmental Quality Act (SB 1334) requires that "significant effects" on oak woodlands be mitigated with measures ranging from conservation easements to oak plantings. Moreover, the law requires monitoring to ensure the mitigation's success.

In December, IHRMP will offer the first in a series of Oak Woodland Planner's Workshops in Auburn, a fast-growing part of the Sierra Nevada foothills. The topics include implementing state laws that affect oak woodlands, and strategies for conserving them. Planning approaches include protecting large tracts of oak woodland by, for example, clustering rural developments, containing sprawl with urban growth boundaries, and minimizing invasive, nonnative plants in rural residential areas.

"We help preserve, protect and provide alternatives for oak woodlands," Bartolome says. "It's important to give people viable options."

— Robin Meadows

Useful links:

California Oak Foundation
www.californiaoaks.org/index.html

California Oak Mortality Task Force
http://nature.berkeley.edu/comtf

California Wildlife Conservation Board's Oak Woodlands Conservation Program
www.wcb.ca.gov/Pages/oak_woodlands_program.htm

UC Integrated Hardwood Range Management Progam
http://danr.ucop.edu/ihrmp

IHRMP Oak Woodland Planner's Workshops
http://danr.ucop.edu/ihrmp/oakworkshop/index.html

RESEARCH ARTICLE

Blue oak seedling age influences growth and mortality

by Ralph L. Phillips, Neil K. McDougald, Doug McCreary *and* Edward R. Atwill

In some California locations, the natural regeneration of blue oak is limited by the ability of small seedlings to survive long enough to become larger saplings. This study evaluated the growth and survival of different age classes of seedlings. We found that over a 7-year period, older blue oak seedlings had a much higher survival rate than younger seedlings. Under this study's conditions, however, the height of younger seedlings increased while that of older seedlings decreased. These results suggest that once a seedling survives approximately a decade and becomes established, it is much more likely to remain alive compared to newly germinated seedlings. Nonetheless, its height growth rate may be extremely slow.

California's oak woodlands are critical, providing rich wildlife habitat, soil stabilization and beautiful scenery, as shown at the UC Hastings Natural History Reservation in Carmel Valley. Oaks are long-lived but also slow-growing trees; regeneration rates for some species may not be adequate to replace natural mortality.

Blue oak trees are a valuable economic and aesthetic resource in the Sierra Nevada foothills of California. Ecologically, oak woodlands, including blue oak (*Quercus douglasii*) woodlands, provide some of the richest wildlife habitat in the state (Giusti et al. 2005). However, for nearly a century there have been concerns about the adequacy of natural blue oak regeneration (Jepson 1910). In some locations, natural regeneration may be insufficient to sustain populations (Bartolome et al. 1987; Sweicki et al. 1997a), while in others it may be more than adequate to replace mortality (Wieslander 1935). This conflicting information is cause for concern among landowners, governmental agencies, conservationists and others interested in the long-term sustainability of this species (see page 7).

Standiford et al. (1991) conducted an oak-tree size survey in 1987 and found large numbers of blue oak seedlings less than 1.0 feet (0.3 meter tall), fewer seedlings in the 4.3-to-10.2 feet (1.3-to-3.1-meters) category, but an adequate stand of mature trees (at least 100 trees per acre). Swiecki et al. (1997b) also reported insufficient numbers of blue oak saplings at 13 of 15 locations sampled throughout the state to replace tree mortality.

Information regarding the mortality of small oak seedlings is limited and not always consistent. Allen-Diaz and Bartolome (1992) reported 50% annual mortality over a 3-year study, while Swiecki et al. (1991) reported that 75.7% of blue oak seedlings survived over a 3-year study. Neither study identified the age of the seedlings.

Livestock grazing, drought and competition for soil moisture from nonnative annual plants have been suggested as factors that influence blue oak seedling survival, but there is limited biological information about which factors are most important (Phillips et al. 1996).

Age groups and causes of mortality

The first part of this study was initiated in oak woodlands in the southern Sierra Nevada foothills of Kern County, in 1989 (Phillips et al. 1997). At that time, 600 naturally regenerated blue oak seedlings were identified in 13 0.1-acre (0.04-hectare) plots at three locations. In 1993, a technique described by Phillips et al. (1997) was used to estimate the age of the surviving seedlings from this group. The technique involved using regression analysis to develop a model of the relationship between root-crown diameter and the number of growth rings. Root crowns of the seedlings identified in 1989 were measured in 1993 and the regression equation was used to estimate seedling age.

The second part of the study was initiated in 1997. There was a large blue oak acorn crop in fall 1996, and the subsequent winter moisture of late 1996 and early 1997 was adequate to

Oak seedlings often must compete with dense annual grasses for moisture and nutrients, while rodents and livestock browse on them. A long-term study in Kern County assessed the growth rates and mortality of blue oak seedlings (flagged).

support what appeared to be above-normal acorn germination. In spring 1997, a large number of newly germinated blue oak seedlings were present in the 13 plots established in 1989. During early summer 1997, after the annual vegetation had dried so that seedlings could be located more easily, each of the original 13 plots was evaluated for the presence of newly sprouted seedlings. In order for seedlings to be classified as newly sprouted, the acorn had to still be attached to the seedling. Each newly sprouted seedling was identified by a number, plot number and year. Seedlings in the old group in these plots had already been individually identified in a similar fashion.

The 1989 seedlings were the first age group (old) and the 1997 seedlings were the second (new). Seedlings from the 1989 and 1997 groups were evaluated annually from 1997 to 2004. These assessments were conducted at the end of the growing season, when the forage had turned brown.

Height measurements were taken in 1997 and 2001 on both the 1997 (new) and 1989 (old) seedling groups, and mortality was assessed annually. The cause of death was categorized as either rodent-caused or non-rodent-caused. To be classified as rodent-caused, there had to be clear evidence that rodents had destroyed the seedling: either rodent burrows present near the seedling, or if dead seedlings could be pulled up, visible teeth marks on the roots. All other dead seedlings were categorized as non-rodent-caused.

Analysis of age groups and height

In 1997, there were 300 seedlings in the old seedling group and 764 seedlings in the new group. The effect of age group and initial height on absolute height change (height in 2001 divided by height in 1997) and the relative height change ([height in 2001 divided by height in 1997] divided by height in 1997) were analyzed using a generalized least squares regression analysis, with a stratified variance function for each age group due to unequal variance structures (Pinheiro and

TABLE 1. Generalized least squares regression model for relative effects of age and initial height of blue oak seedlings on the change in height, 1997–2001

Factor	Regression coefficient	*P* value*
Model intercept	2.37	< 0.001
Height in 1997 (inches)	–0.72	< 0.001
Age group†		
New seedlings	0.00	—
Old seedlings	–2.05	< 0.001
Height in 1997 × age-group interaction		
Height in 1997 × new‡	0.00	—
Height in 1997 × old	0.58	< 0.001

* Significance determined by a conditional *t*-test.
† New = 1997; old = established prior to 1997.
‡ Referent group of seedlings for the regression model.

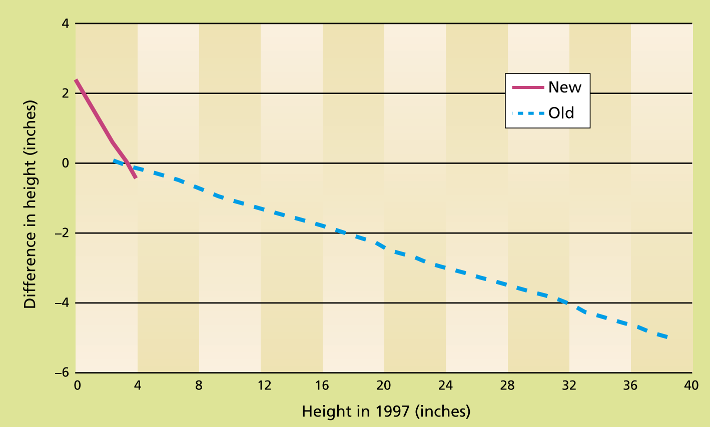

Fig. 1. Effect of age and initial height of blue oak seedlings on the difference in height, 1997 to 2001.

Oak seedlings are often repeatedly browsed by animals such as deer, keeping them small and stunted for decades.

In 1989, the estimated age of this seedling was 11 years.

Bates 2000). The initial height, average age in 1997 and average age in 2001 were analyzed using analysis of variance. The percentage annual death rate was analyzed using a linear mixed-effects regression model (Pinheiro and Bates 2000) after the outcome variable had been transformed using an arcsine transformation (Neter et al. 1990). The percentage annual death loss was calculated as the number of seedlings that were alive the previous year divided into the number of seedlings that died during the following year. The survival and height data reported were from those seedlings not affected by rodents.

Changes in height

The overall mean height in 1997 was 2.0 inches (5.0 centimeters) for the new group of seedlings and 12.0 inches (30.0 centimeters) for the old (established) group. The 2001 average height was 3.0 inches (7.4 centimeters) for the new group and 11.0 inches (27.4 centimeters) for the old group, with an overall mean change in height of 0.96 inch (2.4 centimeters) and –1.0 inch (–2.5 centimeters), respectively. The generalized least squares regression model showed a significant difference in the change in height between the new and old seedling groups (table 1).

However, this difference was strongly influenced by the initial height of the seedling in 1997 (fig. 1). In other words, regardless of whether the seedling was new or old (established), the taller it was in 1997, the more likely it was to lose height during the 4-year study interval. This was most likely due to the dieback of shoots from lack of moisture. Consistent with this result, Phillips et al. (unpublished data, 2004) observed that shorter seedlings increased in height faster than taller seedlings over a 12-year observation period. In this larger study, 599 seedlings were initially followed from 1998 to 2001, in the same location as the present study.

Similar to the results shown in table 1, the generalized least squares regression model for the percentage change in height between 1997 and 2001 (table 2) showed a significant difference between the old and new seedlings. While the majority of new seedlings gained 50% to 200% in height relative to their 1997 levels, many older seedlings lost 10% to 30% of their height. This difference in the relative percentage change of height was strongly influenced by the initial height of the seedling in 1997.

Mortality and survival

The initial height of seedlings in the old group that died between 1997 and

TABLE 2. Generalized least squares regression model for relative effects of age and initial height of blue oak seedlings on relative percentage change in height, 1997–2001*

Factor	Regression coefficient	*P* value†
Model intercept	2.09	< 0.001
Height in 1997 (inches)	–0.74	< 0.001
Age group‡		
New seedlings	0.00	—
Old seedlings	–2.08	< 0.001
Height in 1997 × age group interaction		
Height in 1997 × new§	0.00	—
Height in 1997 × old	0.73	< 0.001

* Relative percentage change in height determined as height in 2001 divided by height in 1997.
† Significance determined by a conditional *t*-test.
‡ New = 1997; old = established prior to 1997.
§ Referent group of seedlings for the regression model.

TABLE 3. Initial height and age of seedlings that lived or died for new and old age groups, 1997–2001

Seedling status	Average initial height	Average age in 1997	Average age in 2001
	inches (cm)	*years*	
New seedlings*			
Lived	2.1 (5.2)	< 1.0	5.0
Died	1.9 (4.7)	< 1.0	2.2
Old seedlings			
Lived	11.6 (29.1)†	11.5†	15.0†
Died	6.5 (16.3)†	6.4†	9.4†

* New = 1997; old = established prior to 1997.
† Means within age groups are different at the 0.05 level.

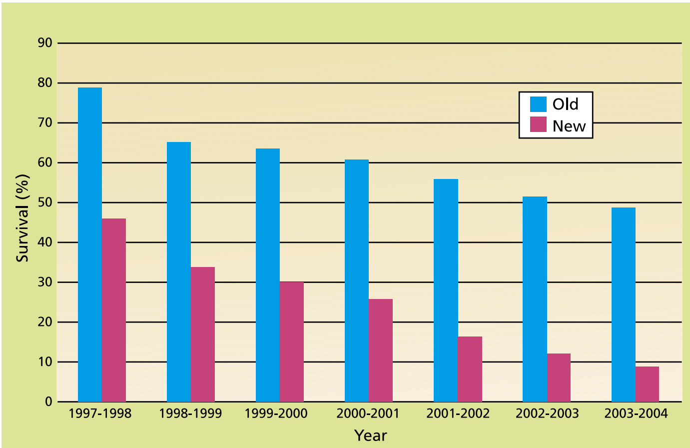

Fig. 2. Observed survival (%) for old versus new seedlings, 1997 to 2004.

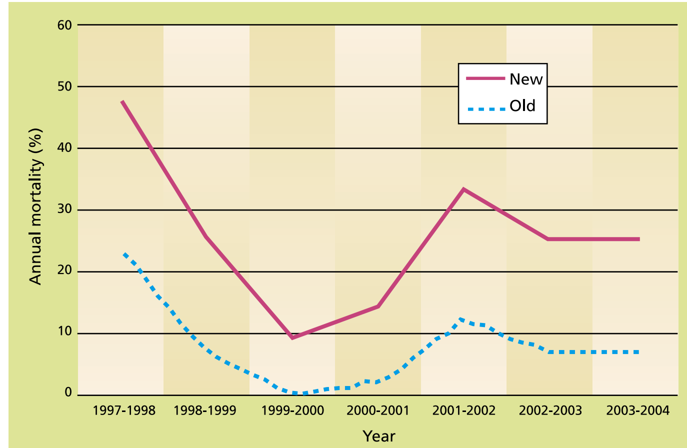

Fig. 3. Average percentage annual death loss for old versus new seedlings from the linear mixed-effects regression model.

2001 was significantly less than the initial height of seedlings that were alive in 2001 (6.5 and 11.6 inches [16.3 versus 29.1 centimeters], respectively) (table 3). Therefore, in the old group shorter seedlings died at a faster rate than taller seedlings. On the other hand, the initial height of

Blue oak seedlings are especially vulnerable to mortality factors when they are young and small.

living seedlings from the new group in 2001 was not significantly different (2.1 inches [5.2 centimeters]) from that of seedlings that died between 1997 and 2001 (1.9 inches [4.7 centimeters]). Phillips et al. (unpublished data, 2004) found that 2.0-inch (5.0-centimeter) seedlings had less than a 10% probability of surviving, while 16.0-inch (40.0-centimeter) seedlings had a 90% probability. However, this relationship did not hold true for the newer seedlings in this study. Also, in Phillips et al. (unpublished data, 2004), shorter seedlings increased in height at a greater annual rate than did taller seedlings.

The average age of surviving old seedlings in 2001 was 11.5 years, and the average age of seedlings that died between 1997 and 2002 was 6.4 years (table 3). The difference in the age of surviving seedlings versus seedlings that died suggests that once blue oak seedlings survive to a certain age, they are much more likely to remain alive than are newly germinated seedlings.

After the first year, only 46.0% of the new seedlings survived, as compared to 79.0% for the old group (fig. 2). By the 7th year, only 8.7% of the new seedlings were still alive, compared to 48.2% of the old seedlings. The linear mixed-effects regression model for the percentage annual death loss shows a significant difference in death rate for the two age groups (table 4). New seedlings died at a significantly faster rate than older seedlings. The death rate caused by rodents was not different between the two groups (about 1.5% for both groups).

Influence of precipitation

Mortality tended to fluctuate from year to year, presumably because of differing environmental conditions (fig. 3). The precipitation for the moisture year 1997-1998 was 27.0 inches (67.4 centimeters), more than double the 40-year average of 12.7 inches (31.8 centimeters). The 1998-1999, 1999-2000 and 2000-2001 annual rainfalls, on the other hand, were closer to the long-term average at 10.6, 12.2 and 9.1 inches (26.5, 30.6 and 22.8 centimeters), respectively. However, there was not a significant correlation between annual death loss and precipitation.

Previous research regarding the relationship between precipitation — or soil moisture — and blue oak regeneration has not been consistent. For instance, a 15-year study by Phillips et al. (unpublished data, 2004) found a significant, positive correlation between annual death loss and precipitation in older seedlings, while Gordon et al. (1991) reported that both the growth and survival of planted blue oak seedlings were positively related to soil water availability. In this study, the effects of precipitation on seedling growth and survival were unclear due to the shorter duration of the evaluation period and the fact that the study was not replicated in different rainfall zones.

Protecting seedlings

The two age groups of blue oak seedlings had different survival percentages and rates of height growth during the 7 years of this study. The data indicates that blue oak seedlings are especially vulnerable to mortality factors when they are young and small. Younger seedlings died at a far faster rate than larger seedlings, but those that remained alive tended to grow faster than their older counterparts. Once seedlings had grown for approximately a decade and become established, however, the chances were good that they would remain alive, although many grew extremely slowly or even diminished in height. If enhancing natural oak regeneration is a goal and efforts are made to protect existing oak seedlings to help them grow to the sap-

TABLE 4. Linear mixed-effects regression model for percentage annual death loss for old versus new blue oak seedlings*

Factors	Regression coefficient	*P* value†
Model intercept	1.53	< 0.001
Age group‡		
New seedlings§	0.00	—
Old seedlings	–0.54	< 0.001
Year		
1998§	0.00	—
1999	–0.45	0.03
2000	–0.88	< 0.001
2001	–0.73	< 0.001
2002	–0.28	0.18
2003	–0.46	0.03
2004	–0.45	< 0.001

* Percentage annual death was arsine-transformed prior to statistical modeling (Neter et al. 1990).
† Significance determined as a conditional *t*-test.
‡ New = 1997; old = established prior to 1997.
§ Referent group of seedlings for the regression model.

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Acorns are a critical food for numerous wildlife species; the acorn woodpecker stores acorns in a dead "granary" tree. In this study, blue oak seedlings became established after about a decade and were more likely to survive than younger seedlings.

ling stage (see page 16), we recommend that these efforts focus on established, older seedlings rather than on newly germinated ones.

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RESEARCH ARTICLE

Exclosure size affects young blue oak seedling growth

by Ralph L. Phillips, Neil K. McDougald, Edward R. Atwill *and* Doug McCreary

Blue oak, a tree native only to California, is notoriously slow-growing, and its low regeneration rate has prompted concern about the species' future survival in some areas of the state. We studied the use of fencing (exclosures) to protect seedlings from herbivores and promote faster growth. Placing exclosures 2 and 4 feet in diameter around blue oak seedlings increased their height and canopy area when compared to a control without exclosures. The 4-foot exclosures increased growth (height and canopy area) compared to the 2-foot exclosures. It appeared that exclosures reduced damage from both wild and domestic herbivores, resulting in accelerated growth rates.

Blue oak, a California native tree, grows extremely slowly, and young seedlings are particularly vulnerable to livestock grazing. Simple fencing exclosures help to protect seedlings and increase the growth of individual trees.

The lack of regeneration by blue oak in some areas of California and the small numbers of seedlings in the 1-to-10-foot (30-centimeter-to-3-meter) height class has caused concern among landowners and environmentalists (see pages 7 and 11). Considerable research has been conducted to evaluate methods for increasing the growth of blue oak (*Quercus douglasii*) seedlings and small trees. In *Regenerating Rangeland Oaks in California* (2001), McCreary summarized research on various aspects of oak regeneration, including planting acorns, protecting seedlings during early growth stages, and fencing to exclude livestock and wildlife from native and planted oak seedlings. He found that such exclosures were effective in reducing browsing by wildlife and domestic livestock.

Many owners of oak rangeland have native blue oaks that are 1 to 6 feet (0.3 to 2 meters) tall, but that are growing very slowly. Also, landowners may have seedlings in certain areas of their property where they would like to have large trees in the future. These landowners need a method to increase the growth of individual trees.

This study was initiated to develop a method for increasing the growth of selected blue oak seedlings. The study compared the growth of unprotected seedlings to those within 2-foot (0.6-meter) and 4-foot (1.2-meter) diameter exclosures. The hypothesis was that 4-foot exclosures would protect the horizontal growth of seedlings more than 2-foot exclosures, increasing the biomass of seedlings.

Study sites, statistical methods

In 1997, eight oak woodland sites were identified on four ranches in the southern Sierra Nevada foothills of Kern County. Ranches 1 and 4 had two sites each, ranch 2 had one site, and ranch 3 had three sites. Each site had 10 to 15 seedlings per acre (25 to 38 per hectare) that were 10 to 30 inches (25 to 75 centimeters) tall. Three similarly sized seedlings from each site were randomly assigned to one of three treatments: control (no exclosure), 2-foot-diameter exclosure and 4-foot-diameter exclosure. Initial and yearly measurements were made for seedling height and canopy area in late June or early July, after the current year's height increase had slowed. Height measurements were taken from the seedling's base to the top of the tallest green shoot.

We assumed that the canopy of a seedling is approximately circular, so the canopy area was calculated using the formula for the area of a circle (πr^2). The radius was determined by averaging the longest and shortest diameters of the seedling canopy and dividing by 2. Each seedling was examined to determine if there was girdling caused by rodents. Girdling is the removal of bark from all or part of the circumference of the tree, which in this study was visually observed up to 4 inches above ground level.

Oak woodlands provide a distinctive character to the state's visual landscape.

The exclosures were constructed using 0.25-inch (0.6 centimeter) welded-wire commercial cattle panels. The panels were 54 inches (1.4 meters) high by 16 feet (4.9 meters) long. The panels were cut in 8-foot (2.4-meter) lengths and molded into 2-foot-diameter circular exclosures. The 16-foot panels were molded into 4-foot-diameter circular exclosures. The exclosures were centered around the seedlings and two T-posts held them in place.

The annual percentage change in height and canopy area were calculated using this formula: $([\text{Year}_{i+1} - \text{Year}_i]/\text{Year}_i) \times 100$, and the accumulated percentage change for the two experimental parameters was calculated using this formula: $([\text{Year}_i - \text{Year}_1]/\text{Year}_1) \times 100$, with i being the study year from 2 through 8.

The effects of exclosure diameter on the annual as well as accumulated height and canopy area of blue oak seedlings were determined by using a generalized least squares regression model (Pinhiero and Bates 2000). Using a backward-stepping algorithm, year, exclosure diameter (0, 2 or 4 feet) and their interaction term functioned as covariates, with a P value of less than 0.05 as the cutoff point for retention of the term in the model. If the interaction term was found to be significant, all single-level terms were retained in the model. In addition, an exponential variance function was added to control heteroscedacity (unequal variance) of within-group errors, along with an adjustment for serial correlation induced by repeated annual measurements on the same set of seedlings. Each of the four outcome variables (annual height, cumulative change in height, annual canopy area and cumulative change in canopy area) was evaluated separately.

Seedling height and canopy

A comparison of the raw data for average seedling heights (fig. 1A) and canopy areas (fig. 1B) for the three treatments (0, 2- and 4-foot exclosures)

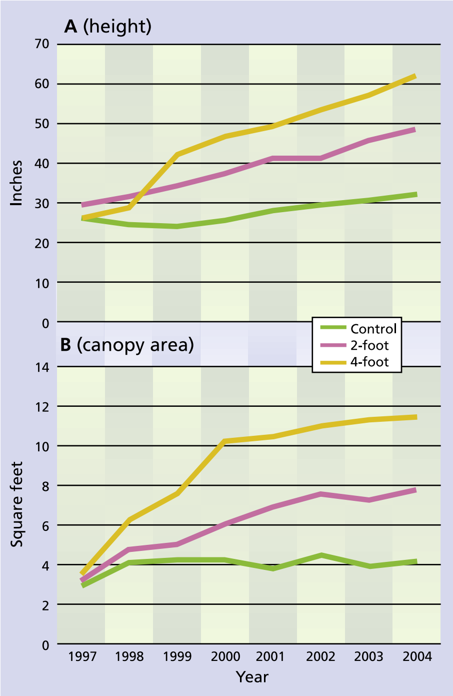

Fig. 1. Raw data for (A) height and (B) canopy area of blue oak seedlings for three treatments, 1997 to 2004.

Jack Kelly Clark

Repeated browsing by deer and cattle can stunt oak seedlings.

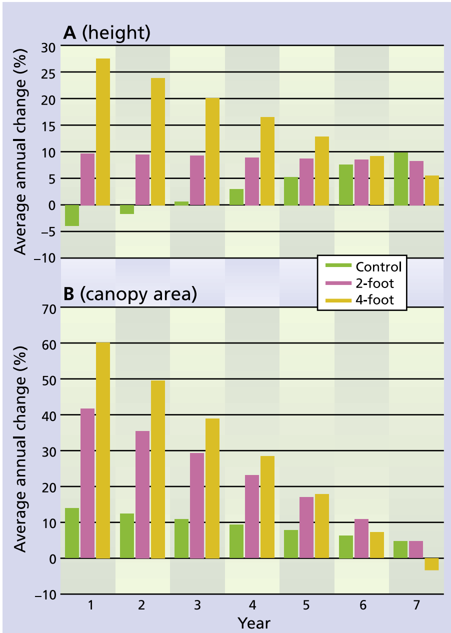

Fig. 2. Generalized least squares (GLS) regression model showing the average trend in the raw data for the percentage annual change in blue oak seedling (A) height and (B) canopy area for three treatments, 1997 to 2004.

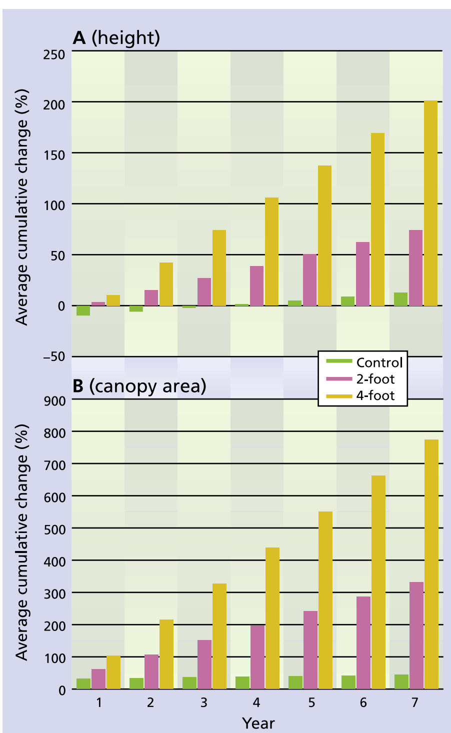

Fig. 3. GLS regression model showing the average trend in raw data for cumulative percentage change in blue oak seedling (A) height and (B) canopy area for three treatments, 1997 to 2004.

during the study's 8 years shows generally slow but steady growth for all treatments. Using the regression equations to represent average trends in the raw data, seedling height increased more than 20% per year during the first few years for the 4-foot exclosure group, with reduced rates of growth thereafter (fig. 2A). In comparison, the 2-foot group had a relatively steady annual height increase of about 9% to 10%. The control group lost height during the first few years (–3.9%) — potentially due to herbivory — but exhibited annual height increases of 5% to 10% during the last few years of the study. By the 7th year, all groups were growing about the same, with 7% to 9% annual height change (fig. 2A).

Using the regression equations to represent average trends in the raw data, there was a significantly higher increase in canopy area during the 1st year for the 2-foot and 4-foot groups compared to the control group (control = 13.9%; 2 foot = 41.6%; and 4 foot = 60.1%) (fig. 2B). By the 5th year the annual change in canopy area was only 7.8% for the control group, compared to 17.0% for the 2-foot group and 17.8% for the 4-foot group.

The percentage accumulated height and accumulated canopy area for the three groups were not significantly different, but there were significant interactions between year and exclosure diameter. Using the regression equations to represent average trends in the raw data, by the 7th year the height of seedlings in the 4-foot group had increased by 200%; the 2-foot group had increased by 74%; and the control seedlings had also increased, but by only 12.8% (fig. 3A). The average trends for canopy area follow the same general pattern (control = 44.0%; 2 foot = 331%; and 4 foot = 775%) (fig. 3B).

The substantially greater increase in height and canopy growth during the first several years of the study exhibited by the seedlings in the 2-foot and 4-foot exclosures compared to the seedlings outside of exclosures (control group) resulted in greater height and wider canopies for those seedlings located inside the 2-foot or 4-foot exclosures. Examination of the raw data demonstrates that in 2003 the average height for a seedling in the 4-foot exclosure group was about 58 inches, and the average height for those in the control was about 30 inches (figs. 1A and 1B).

Using the regression equations to represent average trends in the raw data, the annual percentage growth was 10% for the control group and 5.6% for the 4-foot group in 2004.

Blue oak seedlings protected for 8 years by 2- and 4-foot exclosures had significantly wider canopies and greater heights than those in the unprotected control group. This simple and relatively inexpensive method provides rangeland owners and managers with an effective option for encouraging oak regeneration.

Therefore, the average increase in height for the control group in 2004 would be about 3.0 inches (30 inches × 10%). The average increase in height for the 4-foot group would be 3.25 inches (58 inches × 5.6%). The greater annual growth rate for the 4-foot and 2-foot exclosure groups resulted in taller seedlings in these groups than in the control during the first years of the study. As a result, by 2004 the average cumulative growth was much greater for the 4-foot and 2-foot groups, even though the average annual growth was similar for the three groups by the end of the study.

The hypothesis that the 4-foot exclosure treatment would allow seedlings to grow more when compared to the 2-foot exclosure treatment was confirmed. The average increase in height for seedlings in the 2-foot group was only 19.4 inches, while that for the 4-foot group was 36.7 inches.

Making the assumption that an increase in canopy area translates into an increase in leaf area, and consequently more growth (height and canopy area), helps to explain why the seedlings in the 4-foot group were taller after 8 years. The average canopy area for the 4-foot group increased more during the first several years of the study (fig. 1B). By the end of the study, the average canopy areas for the 4-foot and 2-foot groups were 11.5 square feet and 7.8 square feet, respectively.

Threats from animals

Mice, rats and/or voles can be a troublesome threat to blue oak seedlings. These animals thrive in dense vegetation, groundcover and thatch (McCreary 2001). Rodents such as voles can girdle oak seedling shoots, either killing the aboveground stem or slowing growth but not killing the seedling. Phillips and McDougald (1998) compared the rodent girdling of blue oak seedlings growing in 16-foot-by-16-foot livestock and wildlife exclosures to those in open grazing areas. The 1998 comparison was made in a habitat similar to that of this study. After 5 years, 85% of the seedlings growing in the large exclosures had been girdled, compared to 21% in the grazed areas.

In this study, we used much smaller exclosures compared to the larger 16-foot-by-16-foot ones in the Phillips and McDougald (1998) study. We did not observe any seedling girdling in the present study, apparently because there was not sufficient groundcover in the exclosures for good rodent habitat. This supports McCreary's (2001) conclusion that without adequate habitat, vole damage to oak seedlings is eliminated or reduced.

In general, the smaller 2-foot and 4-foot exclosures used in our study provided an effective method for limiting damage to blue oak seedlings from both small (voles) and large (wild and domestic) animals. Exclosures of excessive diameter, such as 16-feet-by-16-feet, may limit herbivory from large animals but lead to excessive girdling by rodents.

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RESEARCH ARTICLE

The Coyote Lure Operative Device revisited: A fresh look at an old idea

by Are R. Berentsen, Robert M. Timm
and Robert H. Schmidt

We field-tested the Coyote Lure Operative Device (CLOD), a bait delivery system for coyotes originally conceived by UC Davis researchers in the 1980s. Our objectives were to determine whether free-ranging coyotes would activate CLODs repeatedly when exposed to them over a 12-month period, and whether CLOD activations varied by season. We placed CLODs in pastures with a history of chronic sheep depredation at the UC Hopland Research and Extension Center in Mendocino County. Free-ranging coyotes activated the CLODs repeatedly, but more CLODs were activated during the winter months than at other times of the year. Our study suggests that the CLOD has the potential to become an important tool for managing coyote predation on livestock when used to deliver contraceptive or predacide baits.

A coyote chews on a Coyote Lure Operative Device (CLOD), captured by remote camera at the UC Hopland Research and Extension Center in Mendocino County. *Inset*, a cluster of nine CLODs with some chewed open.

Predators killed an estimated 224,200 sheep and lambs nationwide in 2004, costing livestock producers an estimated $18.3 million (NASS 2005b). As livestock depredation continues to rise, the livestock industry faces the same old dilemma: how to stop predators, primarily coyotes (*Canis latrans*), from killing livestock. In 2004, 135,600 sheep and lambs were reported lost to coyotes alone, representing 60% of losses due to all predator types and a financial loss of about $10.7 million (NASS 2005b).

While the total losses may not seem overwhelming, they are not distributed evenly across all livestock producers. Because of where they are located, some producers sustain such heavy predation that they cannot operate profitably. Sheep inventories have declined in California in recent decades, from 1.12 million in 1994 (NASS 1995) to 680,000 in 2004 (NASS 2005a), as they have nationwide. In 1942, sheep and lamb inventories were approximately 56.2 million head (NASS 2000) whereas 2004 inventories were just over 6.1 million. Nonetheless, the total number of breeding ewes in California remains second nationwide (680,000 head), following only Texas (1.1 million head) (NASS 2005a).

In California, an added complication to coyote control is the 1998 ban on leghold traps and certain toxicants (such as predacides, chemical compounds used to kill predators). These have traditionally been among the most important tools used by livestock producers and predator management professionals to control problem coyotes. In recent years, similar trap or toxicant bans have been enacted in several other states with significant urban populations (Minnis 1998). This has prompted researchers to investigate new methods of predator management as well as to revisit older ideas.

Coyote Lure Operative Device

Marsh et al. (1982) at UC Davis first conceived the Coyote Lure Operative Device (CLOD) as a tool to deliver chemical agents — such as toxicants, contraceptives or pharmaceuticals — to targeted coyotes. The current model, adapted in large part from Marsh et al. (1982), consists of a 1-ounce plastic vial with a rigid nylon core that is collectively called the “unit head.” The unit head is attached by a nylon wing nut to a steel stake anchored into the ground. Because coyotes like sweet-tasting compounds (Mason and McConnell 1997), the unit head is filled with a corn syrup and powdered-sugar mixture (Ebbert 1988). In addition, a commercial coyote attractant designed to elicit biting is applied to the outside of the unit head. Coyotes activate the CLOD by chewing it open and ingesting the contents. After they first ingest the contents of the CLOD, the sweet reward encourages repeat visits (Barnum et al. 1982; Berentsen et al. 2006).

Previous research at the UC Hopland Research and Extension Center (HREC) has shown that paired (male and female), territorial coyotes were responsible for the majority of lamb losses (Jaeger et al. 2001). These older, dominant (alpha) animals are notoriously difficult to target and remove using traditional control tools and methods (Sacks et al. 1999; Windberg and Knowlton 1990).

CLODs hold the potential to be a selective, efficient tool for managing coyote predation.

We theorized that coyotes could be conditioned to activate CLODs by filling them with a placebo corn syrup solution and then placing them in areas of high coyote activity or pastures with traditionally high livestock losses. Once frequent or regular activation of CLODs was taking place, it would then be possible to add an approved toxicant to the sweet mixture if and when predation began to occur.

In November 1998, California voters passed a ballot initiative banning the use of the two toxicants that were then registered for use in coyote control, sodium cyanide and Compound 1080. Currently, researchers at the U.S. Department of Agriculture's National Wildlife Research Center are pursuing the development of a new toxicant for coyotes, which could be delivered via the CLOD. Initial research suggests that this toxicant is selective for canids and may be more humane than earlier coyote toxicants (Johnston 2005).

Alternatively, the CLOD could be used to deliver a chemical sterilant to prevent coyote reproduction. In studies of coyotes in the intermountain West, the surgical sterilization of coyotes dramatically curtailed livestock depredation (Bromley and Gese 2001). Moreover, Buseck (2004) successfully used the CLOD to deliver oral contraceptive agents to captive coyotes. Research to find an effective coyote sterilant that can be successfully delivered orally to wild coyotes is currently in progress at several facilities.

The objectives of our research were to determine whether free-ranging coyotes would activate CLODs repeatedly, and whether the frequency of activation would change throughout the year. Berentsen et al. (2006) found that captive coyotes would approach and activate CLODs, somewhat warily upon first exposure, but then quickly and repeatedly when exposed to them daily over a 4-day test period. In previous research, free-ranging coyotes activated CLODs at approximately the same rate as M-44 sodium cyanide ejectors (Ebbert 1988), when both devices were placed in a typical rangeland environment. In addition to testing CLOD activation, we used remote cameras to photograph animals that investigated and activated CLODs. Photographs were also used as a reference to identify whether the same or different coyotes were approaching and activating the CLODs.

Attracting coyotes to CLODs

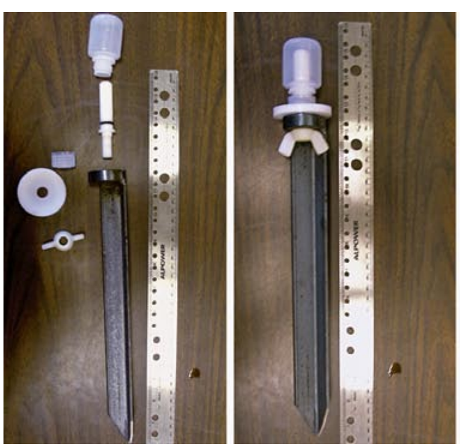
HREC is a working sheep ranch in Mendocino County, which maintains a large flock of sheep and lambs year-round (700 to 1,500 head) and suffers high levels of predation by coyotes (Scrivner et al. 1985). This facility has been the site of coyote research for more than 30 years and was the location of some of the early CLOD research (Timm and Vaughn 2003). Coyote control is actively conducted at HREC to protect the research sheep flock, but lethal coyote removal was temporarily suspended during this study. (Coyotes are normally shot by on-site personnel, and state wildlife services specialists perform some snaring.)

To tag coyotes, we captured them using wire snares that had been modified to prevent mortalities. Snares were checked daily in the morning. Captured coyotes were fitted with color-coded leather collars and numbered ear tags. Capture efforts were conducted from June 2004 through May 2005.

During this period, we also placed CLODs along roads and trails frequented by coyotes as well as in pastures with a history of sheep predation. Four remote cameras (Trailmac, Trailsense Engineering, Middletown, Del.) were placed at clusters of six to nine CLODs. The CLODs were checked twice every week and the cameras were checked weekly. Based on the recommendations of professional trappers and previous research, we used the following three commercial coyote attractants/scents in the study: Powder River (PR), Government Call (GC) and Subdued (SD) (O'Gormans, Broadus, Mont.). A synthetic attractant called Fatty Acid Scent (FAS) (Pocatello Supply Depot, Pocatello, Ind.) was added during winter months and was used continuously for the duration of the study (table 1). During the fall and winter, attractants were applied to the CLODs via a mixture of melted paraffin, in order to decrease volatilization of the lures and reduce the potential for rain to wash the attractants away.

Use peaks in winter

We captured, marked and released 16 coyotes. Half were female and half were male, and most were yearlings.



Left, **a disassembled CLOD with individual components.** ***Right***, **the current model of the CLOD, fully assembled.**

CLODs chewed by, ***left***, **an opossum and,** ***right***, **a coyote. The devices contain a sweet-tasting mixture plus a commercial attractant or scent. Once coyotes are habituated to consuming the CLOD's contents, wildlife managers can add toxicants or sterilants to control problem animals and protect livestock.**

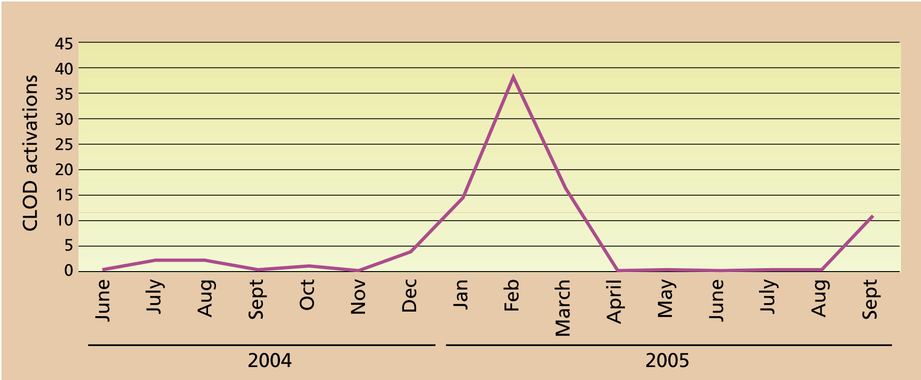


Fig. 1. Number of CLODs activated by coyotes, June 2004 to September 2005.

Twelve of the coyotes were captured between October 2004 and March 2005. One was recaptured and several others were subsequently sighted at HREC and adjacent properties.

While we did not photograph any marked coyotes approaching or activating the CLODs, we did take four photographs of three different coyotes. Other species photographed approaching the CLODs included sheep, deer, turkey vultures, wild turkeys, opossums, skunks, bobcats, cattle, raccoons and domestic dogs. Besides coyotes, opossums were the only animals photographed chewing on CLODs. The CLODs activated by coyotes were typically chewed open at the top, with little or none of the corn syrup mixture remaining; those chewed by opossums were covered with small holes, which allowed the contents to drain onto the ground.

From June 2004 through September 2005, coyotes activated 88 CLODs. Of these, 29 were scented with FAS, 55 with GC and two each of SD and PR (table 1). Altogether, there were only nine CLOD activations by coyotes during the first 7 months of the study: two in July, two in August, one in October and four in December 2004.

In contrast, many more CLODs were activated during the next 3 months of the study (fig. 1). Coyotes activated 68 CLODs from January through March 2005. In addition, CLODs were activated by coyotes on a weekly basis at two locations. Sheep actively grazed one location, and the other was more remote and ungrazed. Several miles separated these pastures, making it unlikely the same coyote was activating CLODs in both locations. It is possible that the CLODs had been placed along a territorial boundary and that activation was taking place during "perimeter patrols." It is also possible that coyotes trespassing from a neighboring territory were activating the CLODs, similar to Windberg and Knowlton's (1990) finding that coyotes are more likely to be trapped while trespassing than in their own territory.

After March, coyote CLOD activation dropped again. No CLODs were activated from April through August, and 11 CLODs were activated in September. During the peak CLOD activation period (January through March), GC and FAS were the only two attractants used. Roughly half of each type was activated: 20 of the 44 FAS-scented CLODs, and 48 of the 88 GC-scented CLODs.

Because CLOD activations peaked from January through March, we theorize that there may be a seasonal pattern to activation as a result of increased coyote movement, the attractants used or seasonal behavioral changes. Sodium cyanide ejector devices (M-44s), which have been used by predator control professionals for decades and employ odor attractants to stimulate coyote activation, are known to be most successful during cooler months of the year (Phillips and Nunley 1995). The summer drop-off in activations occurred even when coyotes had already learned that a sweet reward was available in the CLODs.

Coyote-selective devices

Our data suggests that CLODs with both FAS and GC were activated in proportion to their availability during the winter and early spring, when activations peaked. In some cases where clusters and transects of CLODs contained both FAS and GC scents, there appeared to be a bias toward FAS. For example, in a cluster of nine CLODs containing six scented with GC and three with FAS, all three FAS-scented CLODs were activated but none of the six GC-scented CLODs were chewed.

We determined that free-ranging coyotes will activate CLODs repeatedly. DNA obtained from two chewed CLODs at HREC determined that the

TABLE 1. Total number of CLODs available and activated in each scent category, Hopland, 2004–2005

	Government Call		Fatty Acid Scent		Subdued		Powder River	
Month	In place	Activated	In place	Activated	In place	Activated	In place	Activated
June 2004	0	0	0	0	0	0	99	0
July 2004	67	2	0	0	7	0	26	0
Aug 2004	79	0	0	0	30	2	29	0
Sept 2004	79	0	0	0	30	0	29	0
Oct 2004	79	0	0	0	31	0	29	1
Nov 2004	79	0	0	0	31	0	29	0
Dec 2004	79	0	31	3	0	0	29	1
Jan 2005	88	14	39	0	0	0	0	0
Feb 2005	85	28	44	10	0	0	0	0
March 2005	85	6	45	10	0	0	0	0
April 2005	69	0	69	0	0	0	0	0
May 2005	69	0	69	0	0	0	0	0
June 2005	69	0	69	0	0	0	0	0
July 2005	69	0	69	0	0	0	0	0
Aug 2005	69	0	69	0	0	0	0	0
Sept 2005	69	5	69	6	0	0	0	0
Total activations		**55**		**29**		**2**		**2**

same yearling male was responsible for both activations. In addition, DNA analysis from CLODs activated at Antelope Island State Park, Utah, during a concurrent study also showed that individual coyotes will activate CLODs repeatedly, but these activations also exhibited seasonal differences (Berentsen 2005, unpublished data). These results suggest that attracting the same coyote to CLODs is possible, but further research is warranted to achieve activation year-round.

Most of the coyotes that we marked were not alpha (territorial) coyotes, and only unmarked individuals were photographed. We had hoped to obtain more photographs of coyotes activating the CLODs, but remote photography is challenging due to the dispersed nature of CLODs when deployed, the cost of camera equipment and the natural wariness of coyotes, especially an alpha pair, toward novel objects. Other researchers have noted that adult dominant coyotes are very difficult to photograph via remote cameras, even in locations where coyotes have not been subjected to control efforts (Sequin et al. 2003). However, our remote cameras provided valuable information about the nontarget species investigating CLODs; they could be a useful tool in future research on nontarget species that investigate bait delivery devices or bait stations. Remote photography indicated that at HREC, we must be attentive to the potential for opossums (a nontarget species) to consume CLOD contents.

Our research suggests that coyotes continue to demonstrate seasonal preferences toward attractants, even when the CLOD offers a sucrose syrup reward year-round. However, coyotes will consume the CLOD contents and multiple CLOD activations are possible, albeit seasonally. Further investigation of various odor attractants and food rewards may enhance the visitation and activation of CLODs by coyotes. While we could not determine whether CLODs would be activated repeatedly by the same free-ranging coyotes, our work with captive coyotes makes us believe that this is so. CLODs hold the potential to be a selective, efficient tool for managing coyote predation when used to deliver toxicants or contraceptive agents. While CLODs will not be a panacea for coyote conflicts with humans and livestock, they may become a useful addition to the dwindling number of tools currently available to landowners and predator management professionals.

***Clockwise from upper left*, visitors to the CLODs included an opossum, sheep, skunk, bobcat, coyote and turkey vulture.**

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RESEARCH ARTICLE

California cotton growers utilize integrated pest management

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Photos: Jack Kelly Clark

In 2000, the UC Statewide Integrated Pest Management Program (UC IPM) conducted a comprehensive survey of pest management decision-making and pest control practices of cotton growers in the 11 major cotton-producing counties of California. The results indicate progress in growers' knowledge and implementation of IPM principles and techniques, although the use of certain aspects, such as treatment thresholds for insects, often fell short of researchers' recommendations. The survey also confirmed the central role of pest control advisers (PCAs) in IPM decision-making. Although independent PCAs communicate more with growers than do PCAs who are affiliated with product suppliers, PCA affiliation did not affect most on-the-ground pest treatment actions measured by this survey. The results indicate a need to expand IPM adoption surveys to include PCAs and to develop more effective ways of measuring IPM decision-making beyond counting the techniques used or not used.

The adoption of integrated pest management (IPM) practices in agriculture has been a goal of federal and state programs since the 1970s and was emphasized by the Clinton administration's target of IPM implementation on 75% of the nation's crop acreage by 2000. The UC Statewide Integrated Pest Management Program (UC IPM 2006) defines IPM as:

> "an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment."

Despite these goals, a recent review of U.S. agriculture by the federal government criticized the lack of progress (GAO 2001). According to this review, while the U.S. Department of Agriculture (USDA) had reported that IPM was being practiced on approximately 70% of U.S. farmland by 2000, much of this perceived progress could be attributed to rudimentary monitoring and prevention practices. More significant practices, such as biologically based pest control methods, had been adopted on as little as 3% and up to 47% of cropland, depending on the crop.

UC IPM was established in 1979 to develop and promote the use of IPM throughout California. The program uses federal Smith-Lever 3(d) funding for IPM extension and outreach, and therefore is required by the Government Results and Performance Act of 1993 to establish methods for reporting program accountability and performance. To meet the requirements of this legislation, the national IPM program requested that UC IPM develop baseline measurements of IPM usage so that future progress could be measured.

Beyond collecting data for reporting purposes, information about IPM adoption will help to address growing public concern about the implications of pesticide use on the environment and human health, and the increasing consumer demand for lower-risk pesticides on food and fiber crops. These demands can only be met by improving our understanding of growers' pest management decision-making processes. With this understanding, we will be better able to direct extension efforts to promote the inclusion of rational decision-making in the choice of pesticides, the increased use of reduced-risk pesticides, and the greater acceptance of biologically intensive practices by growers.

Establishing baseline IPM usage

UC IPM selected two cropping systems in California to begin establishing baseline IPM usage data and examine growers' decision-making criteria. Almonds (Brodt et al. 2005) and cotton were chosen because of their extensive acreage, use of certain high-risk pesticides and long history of UC IPM efforts in promoting IPM. This article reports on results from the cotton survey conducted in 2000 and highlights selected results from the almond survey for comparison. The purpose of both surveys was to assess pest management strategies used by growers; pest management decision-making, including knowledge sources for IPM; and grower familiarity with and attitudes about IPM, as well as other general farm characteristics.

Far left, a cotton harvest and, *left*, cotton flower.

For the cotton survey, growers were randomly sampled from agricultural commissioners' lists taken from 11 counties in the three major cotton-growing regions of California — the San Joaquin Valley (Fresno, Kern, Kings, Madera, Merced and Tulare counties), Sacramento Valley (Colusa, Glenn and Sutter counties) and southern desert (Imperial and Riverside counties). A prescreening process reduced the initial sample of 1,009 growers to a usable sample of 845 eligible growers. To keep the questionnaire at a reasonable length, this sample was split in half. One half of the sample received a questionnaire that included questions about insect and mite management, and the other half received one with questions about disease, nematode and weed management.

Questions pertaining to decision-making, information sources, attitudes toward IPM and demographic characteristics were identical in both versions. All questions pertained to the 1999-2000 growing season.

The protocol used to implement the mail survey was based on the Total Design Method (Dillman 1978, 2000). This approach included a personalized presurvey letter, a questionnaire mailing, a follow-up postcard and a second questionnaire mailing to nonrespondents. An incentive gift, a pocket guide to natural enemies in cotton (Knutson and Ruberson 1996), was enclosed in the first mailing of the questionnaire to all respondents.

A 32% survey completion rate resulted in a final sample size of 266 growers across the three regions (238 from the San Joaquin Valley, nine from the Sacramento Valley, 18 from the southern desert and one for which the region was not identified). Of these 266 growers, 120 completed the insect and mite management version of the questionnaire, and 145 completed the disease, nematode and weed management version. The margin of error is +/– 5.5% at the 95% confidence level.

Mean acreage planted to cotton in 2000 for the entire sample was 1,026 acres, with a standard deviation of 1,945 acres and a range from 14 to 17,000 acres. Respondents represented approximately 29% of the total cotton acreage in the selected regions in 2000.

We used nonparametric statistical tests to analyze the survey data because in some instances the groups being compared had different variances, and in many cases the variables being analyzed were categorical (such as "yes", "no" and "don't know" responses to questions about the use of a practice). We used the Kruskal-Wallis test to assess differences in values of a continuous variable among two or more groups. We used the chi-square statistic to assess differences between two or more groups when categorical variables were involved. Finally, we used Fisher's exact test in cases where the sample size was too small to allow appropriate use of the chi-square statistic.

Common pests and IPM knowledge

Growers were asked to identify whether a given pest was a problem during the 1999-2000 growing season, based on whether they thought it would have caused economic damage to the cotton crop if no control measures were taken. The pest problems experienced by the most respondents included spider mites, Lygus, aphids and damping off (disease-related seeding death). Weeds mentioned included nightshade, annual morningglory, purple and yellow nutsedge, pigweeds, annual grasses and johnsongrass (table 1). This list is similar to one compiled 30 years ago, with five of these nine weeds appearing on both lists (Keeley et al. 1975).

About 14% of respondents indicated that they had never heard of IPM. But among those who had heard of IPM, more than one-third (36%) rated themselves as moderately knowledgeable about IPM and 39% as somewhat knowledgeable. Fewer than one in five (17%) rated themselves as very knowledgeable about IPM. The most common information sources from which growers first learned about IPM were consultants or pest control advisers (PCAs) (26%), UC farm advisors or specialists (19%), UC publications (11%) and trade publications (11%).

Insect and mite management

Monitoring. Careful monitoring of pest populations, especially insect and mite pests, is one of the most important decision-making tools for the IPM practitioner. The survey asked questions about sampling and evaluation techniques available from UC IPM sources for cotton, including the cotton IPM manual (Ohlendorf et al. 1996) and pest

TABLE 1. Pest problems most commonly reported by surveyed cotton growers (n = 94 to 145)

Pest	Respondents
	%
Insects and mites	
Spider mites	74
Lygus	61
Aphids	51
Disease	
Damping off	48
Weeds	
Nightshade	82
Annual morningglory	74
Nutsedge, purple or yellow	70
Pigweeds	65
Annual grasses	57
Johnsongrass	56
Shepherdspurse	51
London rocket	50

management guidelines (Ohlendorf 2005). The vast majority of responding growers who were asked about insect and mite management reported some form of monitoring of Lygus (88%), spider mites (87%) and aphids (90%), mostly via leaf and fruit inspections and/or sweep nets. This figure is roughly comparable to data from a 1996 survey, which found that scouting for insects occurred on 88% of planted cotton acreage nationwide (Fernandez-Cornejo and Jans 1999).

Lygus treatment thresholds. Understanding and following appropriate treatment thresholds is another important aspect of IPM decision-making. Lygus bugs are key pests in cotton and are insidious in their damage. Adults can quickly move into a field and feed on developing flower buds or squares. Since squares are naturally shed as the plant matures, it is important to understand the relationship between plant development, expected square retention and Lygus densities, as presented in the UC pest management guidelines and cotton IPM manual.

In this survey, 66% of respondents reported that they make early-season treatment decisions when the number of Lygus bugs per 50 sweeps exceeds 10, and 47% reported making late-season treatment decisions on the same basis. In contrast, about half (53%) based decisions on fruit retention or loss, and one-fifth (20%) used square damage, insect numbers and UC guidelines for interpreting these numbers. The limited adoption of the complete approach may be related to the time commitment of collecting data and the complexity of interpreting the results.

Spider mite treatment thresholds. Spider mites are small arthropods that are difficult to count and easy to miss. UC IPM supported the development of a presence/absence sampling methodology that was easy to learn and use, and that standardized mite data for the first time (Ohlendorf et al. 1996). Results were presented as percentage of infested leaves in a field. When asked at what level of mite infestation they treat, 51% of growers preferred to treat when fewer than 30% of leaves were infested, suggesting a more conservative approach than is warranted by research on economic injury by spider mites (Wilson 1985). This conservative approach may be a form of risk aversion in response to an absence of effective control measures after plants reach full size. However, regardless of the infestation used to trigger a treatment, the use of presence/absence sampling was almost universal among the respondents.

Steve Wright

Integrated pest management is a strategy for controlling crop pests that combines a range of environmentally beneficial and economically sound techniques. In cotton, this may include choosing herbicide-tolerant varieties or adjusting planting times to maximize plant emergence and vigor.

Aphid treatment thresholds. A similar pattern holds for midseason aphid control, although the thresholds developed from research are currently less certain than for spider mites. Most responding growers (80%) reported treating at fewer than 50 aphids per leaf, while research suggests that an economic threshold occurs between 50 and 100 per leaf (Godfrey and Leser 1999). The challenge to growers, however, is to reduce the aphid population adequately before bolls are open and lint is exposed to insect honeydew, at which time an economic threshold is thought to occur at as few as five to 15 aphids per leaf. After lint is exposed, 71% of respondents treated at 10 to 15 aphids or fewer. “Don’t know” responses for all questions referenced in this paragraph ranged from zero to 10 (9% of responses).

Insecticide use. In spite of these conservative treatment triggers, insecticide use in cotton has declined when measured by the number of treatments per acre (number of acres treated divided by total acres planted), from nine in 1995 to three treatments per acre in 2000, where that level has remained (Goodell et al. 2006).

This change may be associated with growers’ increasing confidence about their understanding of IPM in cotton. For example, when comparing the use of spider mite treatment thresholds with self-rated knowledge of IPM, 80% of growers using the higher threshold of 30% to 50% of leaves infested also rated themselves as very knowledgeable about IPM generally, compared to only 20% of those using 30% of leaves infested, and 14% of those using less than 30% of leaves infested (chi-square $P = 0.07$). There was no significant difference between those using different thresholds for aphids, possibly due to the lesser certainty about what those economic thresholds should be.

Weed monitoring and management

The majority of responding growers who were asked about weed management did not use the more-complex weed management methods oriented toward monitoring and record-keeping. For example, most did not keep records of weed species locations using paper or GPS-generated maps (82% and 96%, respectively, answered “no” to these questions). Furthermore, 63% reported that they did not monitor weeds in untreated areas to detect weed abundance and diversity, and all respondents reported that they did not sample the soil to monitor weed seed abundance and diversity.

In this survey, only about 4% of responding California cotton growers reported using biologically intensive practices such as, *left*, interplanting with alfalfa or, *right*, planting buffer strips to provide alternate habitat for pests and beneficial insects.

However, many growers did indicate that they understood the importance of selecting herbicides based on their ability to target the specific weeds present in their fields. A large majority (94%) reported selecting herbicides based on weed species location and density, suggesting that they did monitor more informally and were aware of which species occur in which areas. This suggestion is further supported by a 1996 survey, which found that 72% of cotton acreage nationwide is scouted for weeds, even though mapping occurs on only 5% of acreage where just preemergent herbicide is used (and where mapping is most needed) (Fernandez-Cornejo and Jans 1999).

Of the responding sample, 68% also considered an herbicide's ability to target specific weeds as a very important factor in choosing a selective herbicide; 84% considered efficacy a very important factor; and 57% valued reduction of the amount of herbicide applied as an important factor. Moreover, more than half (56%) of growers responded that they rotated herbicides to prevent resistance, an important tactic in the face of the increasing incidence of herbicide resistance among weeds.

An integral part of weed management is cultivation, and all responding growers said that they cultivate after cotton emergence and before layby (the period of time after which tractors cannot enter the field due to plant height). In addition, although growers have a number of herbicide options as well as herbicide-tolerant cotton varieties, 73% still hoe by hand for broadleaf weeds and grasses, while 63% hand-pull, rouge or physically remove weeds from the field. On the other hand, most respondents also reported using combinations of chemical (94%) and mechanical weed control (88%) in areas adjacent to fields, with 83% of all 145 respondents indicating use of both strategies.

The planting of genetically modified cotton varieties to facilitate the use of herbicides was relatively common, with 57% of respondents planting glyphosate-resistant (Roundup Ready) varieties and 30% planting varieties tolerant of the herbicide bromoxynil (Buctril; BXN). On the other hand, the increase in planting of glyphosate-resistant cotton has not brought the anticipated decrease in use of preplant-incorporated herbicides such as trifluralin (Treflan) and pendimethalin (Prowl), which 91% of growers still reported using (including 91% of growers planting glyphosate-resistant cotton). "Don't know" responses ranged from zero to seven individuals (5%) for all questions on weed monitoring and control practices.

Grower reliance on PCAs

PCAs play a key role in implementing IPM in California. Creating a successful IPM program requires close association and trust between the field scout, PCA and grower. In rare cases, the same individual might have more than one of these roles; but more commonly, field scouts collect data and PCAs interpret the data to create information for the grower to make pest management decisions.

The reliance on PCAs for pest management advice was almost universal among the survey respondents, with 99% using one or more PCAs. This finding is consistent with the use of PCAs in almonds (Brodt et al. 2005). However, cotton growers used more PCAs per grower than did almond growers; only half (49%) reported using only one PCA (compared to 73% in almonds), while 30% used two (21% in almonds), and 20% used three or more (3% in almonds). The reasons for having more than one PCA visiting a farm may include an increased level of surveillance, the ability to contrast different scouting reports, the specific expertise of different PCAs, and various suppliers competing for business and dividing the fields among PCAs. The difference between almond and cotton farmers in the number of different PCAs visiting is not documented, but it might be related to farm size, the shifting of cotton into different fields annually and crop rotational issues.

The degree of PCA influence on decision-making varies with different pest types. When cotton growers who used PCAs were asked what percentage of the time they follow their primary PCA's recommendations, they reported a mean of 88% of the time for insect and mite pest-management actions (standard deviation = 17%) and

74% of the time for disease management (standard deviation = 35%). For weed management, the mean was 70% (standard deviation = 30%). On the other hand, for nematode management, the mean was only 61% of the time, with a large standard deviation of 45%. Relatively few growers (13%) reported having had nematode problems in the previous 3 years (with an additional 11% unsure), so the result for nematodes is not surprising.

Many of the differences in reliance on the PCA are probably due to the fact that insect and mite management in cotton typically involves more frequent monitoring and continual decision-making over a longer period of time than do disease and weed management. In addition, decision-making must often take into account factors such as treatment thresholds, treatment timings, variable weather conditions, and the balance of pest and beneficial insect populations. These are all factors for which expert input can make a substantial difference in controlling efficacy and cost (Brodt et al. 2005).

On the other hand, decision-making for disease and weed management tends to be concentrated in brief, critical intervals during which long-term decisions are made. In addition, many of these decisions are related to basic cultural practices (for example, the selection of resistant varieties, cultivation and crop rotation), with which growers may feel more confident and less in need of PCA advice. The figures for cotton and almonds were similar for insect and disease recommendations (88% vs. 80% and 74% vs. 78%, respectively), while the percentage following weed recommendations was higher for cotton than for almonds (70% vs. 28%), reflecting the annual versus permanent nature of the cropping systems.

Supplier vs. independent PCAs

IPM is information-intensive in order to decrease risk with increased data. Gathering data by using reliable methodology is only the first step. Communicating and interpreting those field observations in a useful manner is an essential part of the IPM process. This process is conducted by PCAs, who may be independently employed, employed through supplier affiliation or employed in-house by the farm. PCA affiliation is important in an IPM survey because of the perceived bias that can be introduced when those providing advice are also the same people who supply the commercial products.

In this survey, more than half (60%) of responding growers who used a PCA worked most closely with a PCA affiliated with an agricultural products supplier, while one-third (33%) worked with an independent PCA as their primary PCA. An additional 6% reported having an in-house or employee PCA as the primary PCA. These figures closely resemble the results for almonds (Brodt et al. 2005), despite the differences in crop and pest management practices.

Growers who reported consulting an independent PCA as their primary PCA also reported a significantly greater tendency to follow the PCA's recommendations for insect/mite and disease management (Kruskal-Wallis $P = 0.02$ and $P = 0.03$, respectively) than did those who primarily used a supplier-affiliated PCA. The growers with independent PCAs also indicated that their PCAs made more frequent field inspections; 98% of those with independent PCAs reported inspections once a week or more frequently during the growing season, while only 84% of those with affiliated PCAs reported this frequency (chi-square $P = 0.005$) (fig. 1). Growers with independent PCAs were also more likely to receive more frequent verbal reports, with 46% receiving reports twice a week or more, compared to 31% of growers with affiliated PCAs (chi-square $P = 0.01$) (fig. 2).

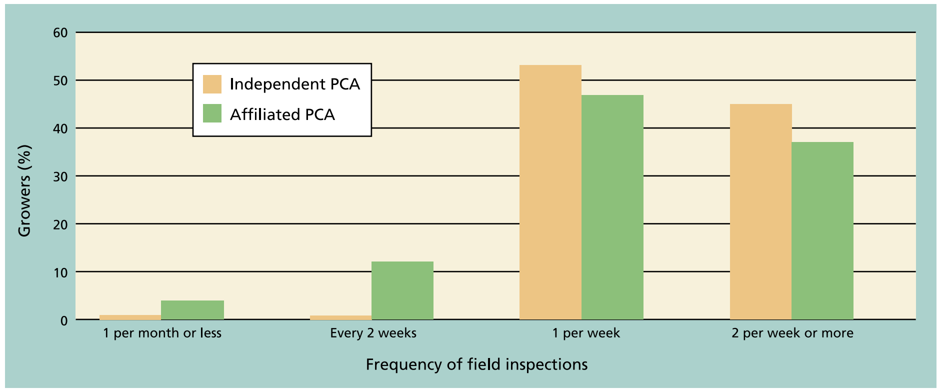

Fig. 1. Frequency of field inspections by primary PCA during peak season.

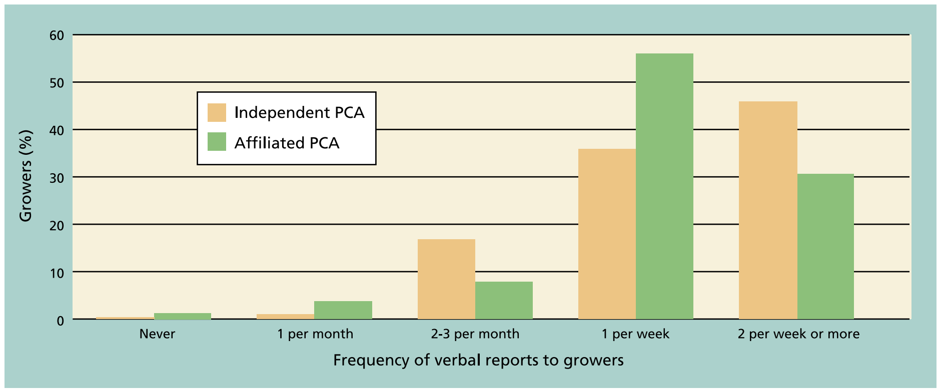

Fig. 2. Frequency of verbal reports to grower by PCA.

Both groups of growers received about the same frequency of written status reports, with 57% of growers with independent PCAs receiving reports once a week, compared to 59% of growers with affiliated PCAs. This frequency was similar for independent PCAs in almonds. However, there was

The reliance on PCAs for pest management advice was almost universal among the survey respondents.

a substantially higher frequency of written reports by affiliated PCAs in cotton than in almonds; for almonds, only 8% reported receiving reports at least weekly. The higher frequency of visits and reporting in cotton than in almonds perhaps reflects the rapidly changing nature of annual field crops compared to perennial tree crops.

Growers with smaller acreage were significantly less likely to use independent PCAs than those with larger acreage. Among our respondents, growers with independent PCAs as their primary PCAs had a mean of 1,129 cotton acres, while growers with supplier-affiliated PCAs had a mean of 667 cotton acres. Those with in-house PCAs had an even larger mean of 4,309 acres (Kruskal-Wallis $P = 0.0002$). This difference might be explained by the economies of scale afforded to PCAs by larger farms. The practice of compensating independent PCAs on a per-acre basis is a disincentive to the PCAs to accept contracts on small farms, where the compensation is small relative to the fixed costs associated with traveling to and from the fields on a regular basis.

Growers using independent PCAs were more likely to consider themselves very knowledgeable about IPM (75%), compared with growers using affiliated PCAs (25%, chi-square $P = 0.04$).

PCA affiliation and pest management

The PCA's affiliation had no influence on growers' tendency to use particular insect and mite monitoring practices or insecticide-related treatment practices, with the exception that growers using independent PCAs were more likely to report the use of sweep nets for aphid and spider mite monitoring. For aphids and spider mites, 72% and 48%, respectively, of growers with independent PCAs reported use of sweep nets, while only 46% and 25% of growers with affiliated PCAs reported using them (Fisher's exact test $P = 0.01$ for aphids and $P = 0.05$ for mites).

PCA affiliation also did not influence herbicide use for weed control, with the exception that 97% of growers with independent PCAs used banded applications, compared to 82% of those with affiliated PCAs (chi-square $P = 0.02$). Glyphosate-resistant (Roundup Ready) varieties were planted by more growers with independent PCAs (72%) than by those with affiliated PCAs (50%; Fisher's exact test $P = 0.006$). Bromoxynil-tolerant (Buctril, BXN) varieties were also planted by more growers with independent PCAs (49% of those with independent PCAs vs. 21% of those with affiliated PCAs; Fisher's exact test $P = 0.004$). On the other hand, no respondents with independent PCAs used light-activated sprayers, compared to 8% (only 10 individuals) of those using affiliated PCAs (Fisher's exact test $P = 0.08$).

Most cultural weed control practices were also used by similar percentages of growers with the two different types of PCAs. The only exceptions were three practices that had either quite low or quite high rates of use overall. Only six growers reported the release of weevils for puncturevine control (a biological control), but three were growers with independent PCAs, two had in-house PCAs (employed directly by the grower), and only one had an affiliated PCA (Fisher's exact test $P = 0.02$).

Keeping records of weed species locations on a paper map (GPS-based recording systems were not widely available in 1999) was reported by only 24 growers overall, but this figure included 26% of all respondents with independent PCAs compared to only 11% of respondents with affiliated PCAs, and 57% of respondents with in-house PCAs (Fisher's exact test $P = 0.02$). These responses suggest that either in-house PCAs have the most time to pursue the more intensive monitoring and control practices, or alternatively, growers with in-house and independent PCAs are more committed to pursuing these types of practices. Finally, only seven individuals reported not using chemical control of weeds in areas adjacent to cotton fields to manage external

Jack Kelly Clark

Pete Goodell of the UC Statewide IPM Program uses a sweep net to monitor insect populations in a cotton field.

sources of Lygus, but all seven were growers with affiliated PCAs (Fisher's exact test $P = 0.08$).

These results in PCA and grower interactions were similar to those reported for almonds, including that farmers who use independent PCAs reported being more knowledgeable in IPM, had larger farms, followed a PCA's recommendation for arthropod and disease management recommendations, and received more frequent field visits and verbal communications. One contrast between the cropping systems was in growers' use of biologically intensive IPM practices based on PCA affiliation. In almonds, growers who used independent PCAs were more likely to use biological and cultural practices in their IPM program. In cotton, this difference was not noted (table 2) except for "Manage the crop for early termination to avoid late whitefly / aphid" (chi-square $P = 0.08$).

Insights for further research

The degree of knowledge about the details of IPM, as shown by farmers in this study, indicates definite success in

TABLE 2. Percentage of responding cotton growers who used various biologically intensive practices, based on affiliation of pest control advisers (PCAs)

Biologically intensive practice	Growers responding affirmative with: Independent PCAs*	Supplier-affiliated PCAs
	. . . . %	
Allow weedy road edges as natural enemy refugia	4	11
Cooperate and time treatments for areawide control	21	15
Consider surrounding crops when choosing location	29	37
Intercrop alfalfa with cotton	4	4
Keep roads watered to minimize dust	79	78
Keep records of natural enemies observed	49	33
Purchase and release natural enemies such as lacewings or predatory mites	8	7
Manage fertilizer to reduce crop attractiveness	47	55
Monitor plant development to time crop termination	96	98
Manage Lygus in surrounding alfalfa by strip cutting	51	36
Plant buffer strips such cowpeas to attract Lygus and natural enemies	4	5
Manage Lygus in neighboring crops such as safflower to mitigate migration	39	45
Manage the crop for early termination to avoid late whitefly, aphid†	38	56
Time orchard/vineyard weed management to limit Lygus movement into cotton	15	20

* Includes in-house PCAs.
† Significant difference (chi-square) at $P < 0.08$.

moving IPM onto farms, especially in the areas of monitoring and decision-making. However, one drawback with this type of mail survey is the inability to distinguish a multidimensional understanding of an agroecosystem — what we might call an "IPM mindset" — from the piecemeal adoption of individual practices.

Investigating this distinction would require a more in-depth and integrated survey or interview process to ascertain whether growers are purposely integrating different pest control strategies and doing so only when they have reached recommended decision criteria, including economic pest thresholds. Such a research project should also obtain objective measures of actual pest pressure faced by growers in any given season. Only then will it be possible to distinguish growers who have yet to try alternative biological practices from those who no longer need to use them because they have managed their system for overall health.

Surveys of pest management practices should also move beyond growers as the primary target. In California, PCAs are recognized as among the most important disseminators of IPM information, especially concerning sampling and the interpretation of pest and natural enemy densities. The role of PCAs in spreading IPM is suggested by our finding of more extensive adoption of IPM practices (such as choosing more selective chemicals, rotating chemicals and pest monitoring) in arthropod control, where growers indicate that PCAs have more influence, than in weed control. Although the present study contributes to our understanding of the importance of PCAs in grower decision-making, it cannot answer questions about PCA perspectives on IPM and whether they themselves have adopted an IPM mindset, or what the role of PCA affiliation is in adopting such a mindset. Surveying PCAs, however, poses many challenges, because they typically work on many farms and commodities at once, and their knowledge and decision processes in any one crop or on any particular farm would be difficult to track.

Finally, discrepancies in the extent of IPM adoption for different pest types also point to a need for more research on effective IPM options for weed and disease control. The relatively low rate of grower adherence to recommended treatment thresholds for arthropod management also suggests a need to reexamine these thresholds in light of growers' on-the-ground constraints in making risk assessments; for example, when they feel they must treat for pests at appropriate times to prevent future population explosions that may be more difficult to handle.

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RESEARCH ARTICLE

High spring temperatures decrease peach fruit size

by Gerardo Lopez, R. Scott Johnson
and Theodore M. DeJong

The growth and productivity of peach fruit can be limited by many factors, including weather. Previous research indicated that early-spring temperatures for 30 days after bloom have a strong effect on early peach fruit growth, and both the time and potential fruit size at harvest. We analyzed fruit-size trends of three major cultivars in the California fresh-market peach industry (Flavorcrest, Elegant Lady and O'Henry) over a 20-year period to determine if there is a clear relationship between early-spring temperatures and packed fruit sizes industrywide. This research confirmed two significant trends: the size of packed fruit has increased over the 20-year period between 1985 and 2004, and high early-spring temperatures tended to decrease the size of packed fruit at harvest for any given year.

An analysis of fruit-size and weather data quantified trends over 20 years in the California peach industry. Temperatures during the 30 days after peach trees bloom can have a strong influence on the size of fruit at harvest.

Over the past few decades, models of peach fruit growth and plant development have identified useful principles for assisting growers in making horticultural management decisions. For example, harvest-date prediction models are now available to aid in managing fruit crops (Ben Mimoun and DeJong 1999). The unusually early harvest of California's peach crop in 2004 — which had record high temperatures during bloom time — and attendant difficulties in attaining the fruit sizes desired by the market (DeJong 2005) have increased interest in using physiological concepts to understand the effects of early-spring temperature on peach fruit growth and in anticipating fruit size at harvest.

The dependence of peach fruit development on spring temperatures during the first 30 days after bloom has been established; there is a strong correlation between the sum of growing degree-hours accumulated in the 30 days after bloom (GDH_{30}) and the number of days between bloom and harvest for several stone-fruit cultivars (Ben Mimoun and DeJong 1999).

Traditionally, the California clingstone peach industry has used reference-date fruit size (the size of fruit at the date of pit-tip hardening, plus 10 days) to predict what the fruit size potential will be for a given year, and then peach growers conduct fruit-thinning accordingly. Reference-date fruit sizes are known to vary from year to year, but the reasons for this variation were previously unclear. Lopez and DeJong (2007) compared a 20-year clingstone-peach data set collected and archived by the California Canning Peach Association, which included full bloom date (FBD), reference date (RD) and fruit size (FS) at reference date from different locations in California.

When the data — collected from orchards near the Central Valley cities of Kingsburg, Modesto and Yuba City — was correlated with seasonal weather data available through the California Irrigation Management Information System (CIMIS), a strong correlation was found between accumulated GDH_{30} and the number of days between full bloom date and

High early-spring temperatures tend to decrease the average size of fruit packed in a given year.

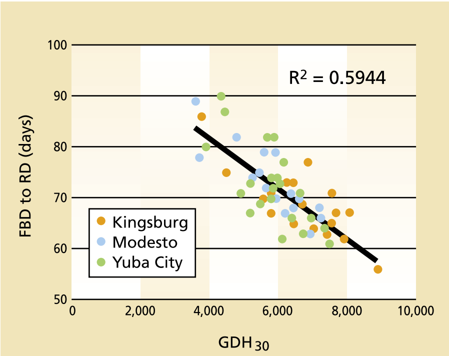

Fig. 1. Accumulated growing degree-hours 30 days after bloom (GDH_{30}) and number of days between full bloom and reference date (FBD to RD) in canning clingstone peaches grown in three California regions (adapted from Lopez and DeJong 2007).

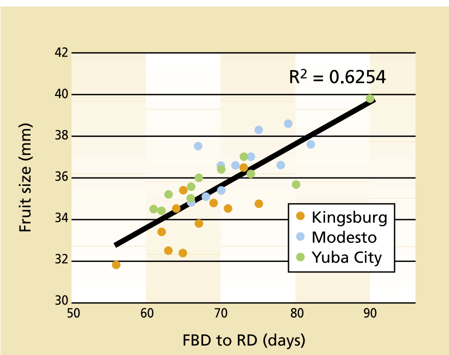

Fig. 2. Days from full bloom to reference date (FBD to RD) and peach fruit size at reference date in canning clingstone peaches grown in three California regions (adapted from Lopez and DeJong 2007).

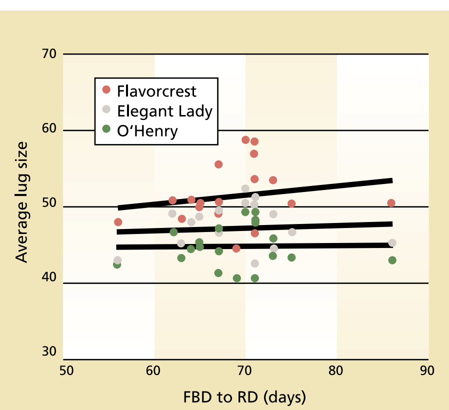

Fig. 3. Days from full bloom to reference date (FBD to RD) for the Kingsburg area, available from the canning clingstone peach industry, and average fruit-size lug at harvest in fresh-market freestone peaches.

reference date (fig. 1). The number of days between full bloom date and reference date decreased as accumulated GDH_{30} increased (fig. 1). There was also a strong correlation between the number of days from full bloom date to reference date, and fruit size at reference date. Fruit size at reference date increased with an increase in the number of days from full bloom date to reference date (fig. 2). This study indicated that peach trees apparently could not supply resources rapidly enough to support the potential maximum fruit growth rates when accumulated GDH_{30} was higher than a threshold value (~ 5,700 GDH). Consequently, fruit size at reference date in years with very warm spring temperatures was less than in years when accumulated GDH_{30} was below that threshold value. Furthermore, previous research has documented that fruit growth potential unfulfilled in early spring cannot be compensated for later in the season (Grossman and DeJong 1995b).

Analysis of fruit-size trends

Although the effects of early-spring temperature on fruit size have been quantified for clingstone peaches at reference date, and fruit size at reference date is thought to be a good indicator of fruit size at harvest, industrywide data on fruit size at harvest is not available from the canning clingstone peach industry. However, the industrywide data situation is the opposite for California fresh-market peaches. This industry does not keep representative seasonal data on full bloom date or reference date, but general fruit-size data is available from industry records maintained by the California Tree Fruit Agreement (CTFA). At the outset of this study, we anticipated that the environmental factors influencing fruit growth and development rates for canning clingstone peaches would be the same as for fresh-market freestone peaches. Thus we initiated a follow-up study using relationships we had established for clingstone peaches to analyze the seasonal environmental effects on industrywide data for the fruit size of freestone peach cultivars.

When fresh-market peaches are packed for shipping, the fruit are separated into different size categories related to the number of fruit that will fit into a standard-size lug box. Fruit packed in a size 30 lug are larger than those in a size 40 lug, while the fruit in a size 40 lug are larger than those in a size 50 lug, and so on. The CTFA annually reports the percentage of the total number of lugs for specific fruit-size categories (% lug size) that are shipped for each major cultivar at harvest.

Data from three different fresh-market peach cultivars (Flavorcrest, Elegant Lady and O'Henry) were used for this study (California Tree Fruit Agreement annual reports from 1985 to 2004) and compared with full bloom and fruit reference-date data for clingstone canning peach cultivars (figs. 1 and 2). However, the average fruit-size lug category of the fresh-market cultivars was not correlated with the number of days between full bloom date and reference date for the clingstone cultivars in a given year in the Kingsburg area (fig. 3).

When we analyzed historical trends in fruit size, there was a clear trend toward lower average lug categories; over the 20 years of this study, the average size of the fruit packed for each cultivar increased significantly (fig. 4). Although improvements in cultural practices may account for some of the increases in packed fruit size, this long-term trend presumably can be attributed to marketing pressures. Consumer acceptance of California peaches has been related to soluble solid concentration, acidity or soluble solid concentration/acidity ratio, but the major quality factor is fruit appearance (Crisosto et al. 1995, 1997). Likewise, market pricing has consistently favored larger-sized fruit.

The percentage distribution trends of average fruit-size categories over the 20 years were similar for the three cultivars, and there were no significant differences in the slope of the regressions between Elegant Lady and O'Henry, or between Elegant Lady and Flavorcrest. However, the slope of the response for Flavorcrest was steeper than for O'Henry (fig. 4).

When the effect of the year on the percentages of four fruit-size lug categories at harvest (30s, 40s, 60s and 80s) was analyzed independently, different patterns were observed among the cultivars and categories (fig. 5). Although all the cultivars increased the percentages of larger fruit-size lug categories (30s and 40s) and decreased the percentages of the smaller fruit-size lug categories (60s and 80s), the slopes of the 30s and 80s categories of Flavorcrest relationships were clearly different from those of Elegant Lady and O'Henry (fig. 5).

The change in Flavorcrest peaches observed in figure 4 could be primarily explained by a drastic reduction in the percentage of fruit packed in the smallest fruit-size lug category (80s) (fig. 5). However, the change observed in Elegant Lady and O'Henry was mostly related to an increase in the percentage of fruit packed in the largest fruit-size lug category (30s) (fig. 5). Although industrywide data on fruit packed per acre is not available for these cultivars, one practical implication of these results is that the average yield of packed fruit has likely declined over the same 20-year period, since, on average, fruit size is generally correlated with crop load (Naor et al. 1999).

For example, a California thinning study showed a substantial effect on yield for both O'Henry and Elegant Lady (Johnson and Handley 1989). For O'Henry, the change in lug size from 1985 to 2004 (fig. 5) required average fruit weights to increase from 0.48

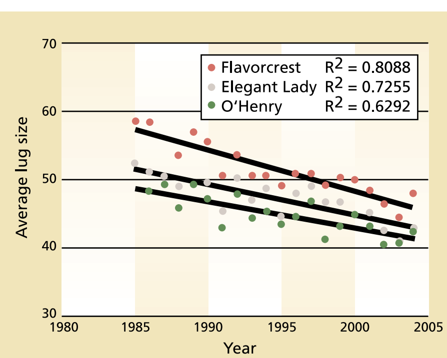

Fig. 4. Year and average fruit-size lugs packed in fresh-market freestone peaches.

Between 1985 and 2004, the average size of fresh-market freestone peaches increased significantly, primarily due to consumer preferences for larger-sized fruit.

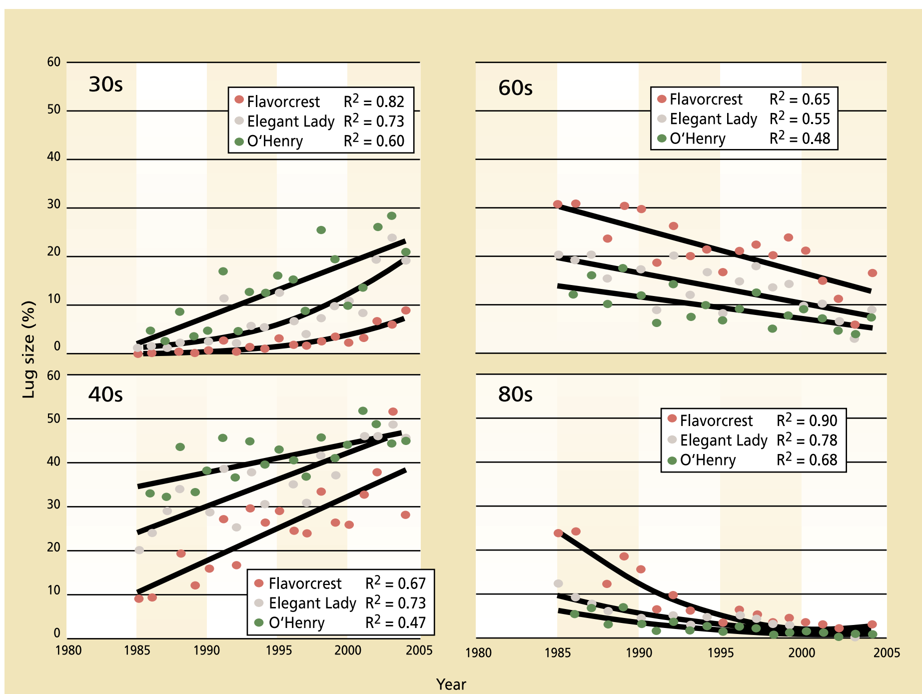

Fig. 5. Year and percentage lugs in four fruit-size lug categories of fresh-market freestone peaches (30s, 40s, 60s and 80s). The relationships between year and percentage of lugs per each fruit-size category were fit to linear or polynomial equations.

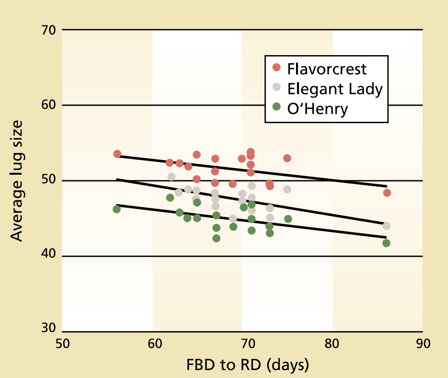

Fig. 6. Days from full bloom to reference date (FBD to RD) for the Kingsburg area, available from the canning clingstone peach industry, and the average adjusted fruit-size lug at harvest in fresh-market freestone peaches, after normalizing the average fruit-size lug data to the long-term industry trends in fig. 4.

In order to accommodate the market for larger peaches, growers can utilize data on early-spring temperatures to predict potential fruit sizes at harvest, and make adjustments to cultural practices such as fruit thinning.

pound (216 grams) to 0.56 pound (253 grams). To obtain these fruit weights, a typical tree would need to be thinned to 976 and 523 fruit in 1985 and 2004, respectively. Thus, yields would have dropped from 464 pounds per tree (211 kilograms) to 291 pounds per tree (132 kilograms), a 37% decrease over the 20 years. The results for Elegant Lady were similar. However, the profitability of early cultivars such as Flavorcrest was probably affected more by market pressures than Elegant Lady and O'Henry, since decreases in the amount of fruit in small-size categories were not offset as much by increases in fruit packed in the large-size categories (fig. 5).

When the data in figure 4 was used to normalize the fruit-size lug data to account for the long-term general trend, the deviation of a given year's average fruit-size lug category from the long-term trend was clearly related to spring weather patterns. The average, long-term, trend-adjusted fruit-size lug category for the fresh-market cultivars in a given year decreased, with an increase in the number of days of fruit growth between full bloom and reference date recorded in the same year for clingstone peaches (fig. 6). Although the variability in this relationship among the different cultivars could have been related to the inherent variability in sources of fruit that were packed, the similarity of the slopes of the relationships for the three cultivars indicates that the conditions driving the relationships were likely similar for all three cultivars (fig. 6).

Practical implications

Previous research with clingstone peaches, combined with this analysis of fresh-market peach data, indicate that early fruit development rates are clearly related to heat accumulation, and that high early-spring temperatures tend to decrease the average size of fruit packed in a given year. This is apparently because in especially warm springs, the tree cannot supply resources rapidly enough to support the potential fruit growth rates associated with high rates of phenological development.

The relationships between fruit developmental patterns, fruit growth potentials and spring temperatures are even more important in light of the clear long-term marketing trends toward packing larger-sized fruit. Grower success will depend upon the ability to anticipate yearly fruit-sizing potential for individual cultivars and make the appropriate, cost-effective adjustments in cultural practices. It is well documented that early and heavy fruit thinning can increase average fruit size, but may cost more and/or reduce overall yields (Grossman and DeJong 1995a; DeJong et al. 1992). However, these practices may be particularly useful in difficult fruit-sizing years in light of the increasing market pressure for large-size fruits.

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RESEARCH ARTICLE

Quality evaluations should not be taken for granted

by Gregory Encina Billikopf

Subjective quality-evaluation errors in agriculture, such as discarding good-quality product and packing poor-quality product, can be costly to growers and workers. This study of workers and supervisors in a strawberry-plant packingshed revealed the danger in assuming that those responsible for quality control truly understand what is required. We found that the ability of workers to correctly count plants, and to retain or reject them (and explain why), varied considerably. The results highlight the need for employers to carefully define quality parameters, and then test employees and applicants. When top management does not agree on exactly what constitutes acceptable quality, it is difficult to expect quality-control inspectors and workers to understand. Testing, as a tool, can help growers and producers make better employee selection and placement decisions and can also be used for periodic training.

Workers in a California packingshed were tested on several tasks related to sorting and packing strawberry plants. Grower Bob Whitaker (right) and his top manager Areli Toledo banter as they review the the plant ratings for specimens that they did not agree on; Toledo scored highest on the test.

Most agricultural tasks require people to make important subjective decisions of a qualitative nature. For instance, should fruit be picked or left on the tree to reach optimal maturity? Should a cow be milked or moved to a hospital to be treated for mastitis? Does a field need to be irrigated? Should a cucumber on a conveyer belt be packed or discarded? Subjective decisions are made at all hierarchical levels, from farm owner to farmworker.

Over the last 2 decades, the author has carried out a number of informal studies in an attempt to measure “rater reliability” in California and Chile. At one operation in Chile, for example, several managers rated the quality of pruning in a fruit orchard and there was no agreement among them. On another occasion, several respected California viticulturalists were asked to rate the quality of 10 grapevines pruned by different employees. After the score sheets were returned, these raters were asked to go back and redo the evaluation. Often their new scores did not agree with their scores from half an hour before (Billikopf 1994, 2003).

While the consequences for incorrect decisions may vary, such qualitative decision-making is usually a key aspect of farming. But at all operational levels, people in agriculture are usually hired without testing their ability to make qualitative decisions. This casual approach to hiring even extends to research assistants, who are most often interviewed but seldom tested for rater reliability; likewise, inter-rater reliability is rarely checked before results are reported. Such a casual approach to selection compromises the integrity of research results as well as farm profits.

Effective human-resource management offers valuable tools to help improve such critical outcomes. Practical tests (also called “job samples”) are an effective and legal way to enhance selection and placement decisions, as well as the training and performance evaluation of present employees (Billikopf 1988, 2003; Federal Register 1978; US Department of Labor 1999).

***Top left*, strawberry-plant workers use a trim tool to cut off plant stems. *Top right*, study participants evaluated 150 numbered samples of strawberry plants, so that their scores could be compared. *Left*, plants suitable for packing should have crowns roughly the size of a pencil, or larger; this root crown is on the small side.**

While the literature mentions the use of testing in agriculture, and even testing that involves the need for test takers to make qualitative decisions (Billikopf 1988, 2003), little has been written on rater reliability in agricultural employment testing (as either a selection, evaluation, placement or testing tool). One exception is Campbell and Madden (1990), in which raters were asked to evaluate the percentage of plant disease incidence in particular samples.

Another example is Mcquillian (2001), who tested medical personnel for how accurately they made decisions regarding medical cases, based on specific guidelines. Much more common is research that studies the reliability of tools or instruments, such as the reliability of a medical survey instrument used for brain injury diagnosis (Desrosiers et al. 1999). Because medical decision-making can have life-and-death implications, it makes sense that much of the work in this field has been conducted in the medical arena.

This study examines whether individuals vary in terms of their ability to make reliable and valid evaluative decisions (that is, their rater reliability), and if this can be measured through the use of a job sample or practical test.

Strawberry-packing study

Data was gathered at a California strawberry-plant packingshed. While the study could have been carried out in any agricultural industry, a task was selected in which workers make multiple quick decisions that can easily be measured against a known standard.

Strawberry plants (for replanting) are harvested in the field and brought to the shed in large, tangled clusters that are separated by workers. Plants are then sorted in terms of a single passing grade (the remaining plants are discarded). Good plants are bunched into groups of 100 units and then packed for shipping nationally and abroad. Sorters are responsible for all the tasks, from untangling the plant clusters to bunching them into 100-plant units. The sorter's most critical job is inspecting each plant and determining if it should be discarded or retained, a task that normally is carried out in less than a second per plant.

After the sorters have done their job, several levels of quality-control personnel inspect the plants. (We define quality control as a system to check that sorters are making correct evaluative decisions.) The two most important quality issues are ensuring that good plants (without defects) are packed and that each bunch contains 100 plants.

While sorters must recognize which plants to retain or reject, quality-control personnel must also be able to understand and describe the reason for rejecting particular plants. This extra detail is needed so that sorters can receive feedback on their performance.

Two salient and costly quality-evaluation errors are (1) discarding good product as not salable and (2) packing poor-quality plants. Discarding good plants is detrimental to both the grower and sorters. The grower loses good plants and all the costs involved in growing them; and the workers, who are often paid on a piece-rate basis, lose good plants they could have packed and earned money from.

A poor-quality pack also has negative economic consequences for the plant buyer, who may cultivate nonviable plants or need to re-sort them beforehand. In order to make up for defective plants, some growers ship an extra 10% free. Growers who ship a

Some of the quality-control personnel did quite poorly in this test, with the super checker doing worse than both the checkers and counters she was supposed to direct.

higher quality pack could gain a competitive edge and positive reputation while saving on plants.

Testing for accurate evaluations

Initial preliminary tests were carried out in December 2004, but the data reported here was collected in September and October 2005. During the initial tests, it became clear that we could not conduct an effective test until top management agreed on what constituted good quality and the reasons for rejecting plants. It took several weeks of negotiation and close work with management to develop a set of known criteria.

Through the testing process we set out to determine how accurately subjects would be able to: (1) count plants per bunch; (2) make reject-versus-retain decisions for each plant; and (3) label the reason for rejecting a plant. To be effective, sorters must make accurate decisions, but not necessarily explain these to someone else. Quality-control personnel, in contrast, must clearly articulate the reason for rejecting plants. Flexibility is required since clients buying the plants can vary in terms of quality pack requirements.

For practical reasons, distinct aspects of the job were tested separately. The first dealt with the accuracy of plant count, and the second with retain-versus-reject reasons. For this study, six distinct reasons were agreed upon for discarding plants. From most serious to least serious, they were: (1) cut crown, (2) black roots, (3) inadequate number of healthy roots, (4) thick crowns, (5) thin crowns and (6) lack of root hairs. For instance, if a plant had a cut crown and black roots, the recorded reason for rejecting it should be the most serious, the cut crown.

Subjects (employees) were shown samples of each discard category and were encouraged to ask questions. Some clearly took better advantage of this opportunity than others.

Subjects, including, *left*, Luz Maria Romero and, *right*, Silvia Araiza, had to make retain-versus-reject decisions for 150 strawberry plants and provide the reason for rejection. Despite the apparent simplicity of the task, few subjects scored well against the known correct answers.

For the retain-versus-reject test, the statistical analysis was adapted from the Gage Repeatability and Reproducibility (Gage R&R) quality evaluation tool. The Gage R&R instrument is often used to test the consistency of a measuring gage in the hands of multiple raters. Here, the instrument being tested was a person rather than a gage.

For both tests we developed an answer key with the known criterion against which subjects would be compared. There was no null hypothesis to test, but rather the ability of each subject to make quick, accurate decisions.

Subjects tested included the grower/shipper, top manager, super checker, checkers, counters and sorters. While the grower and top manager may communicate quality pack standards, it is the super checker who is responsible for checking the work of the regular checkers and counters. The checkers focus mostly on plant quality, while the counters focus on plant count. There is some overlap between the responsibilities of these two job categories.

Accuracy varied widely

Counting. Twenty-four subjects (22 female and two male) participated in the counting test. A total of 2,919 plants were spread out in uneven bunches at 12 stations (bunches ranged from 200 to 300 plants, with a mean of 243 plants).

One subject recorded 818 plants in a station that only had 222, throwing off her score by a large margin. The remaining participants ranged from a total of 12 mistakes (an average of one mistake per station or 0.4% error) to 163 mistakes (more than 13 mistakes per station or 5.6% error).

There was sufficient overlap in terms of subjects who participated in the counting test and the retain-versus-reject test to note that those who could count accurately were not necessarily the same as those who did well in the reject-versus-retain test, and vice versa (table 1).

Retain versus reject. Thirty-two subjects (29 female and three male) participated in the retain-versus-reject test. Two separate sets (A and B) consisted of

150 plant samples each. Subjects were given 5 seconds per plant to make and annotate their evaluative decisions. Plants were labeled from 1 to 150 (in groups of five plants per station, with 30 stations per set).

Subjects were divided into two groups, half in set A and half in set B. Each subject evaluated the set of samples to which she or he was assigned twice. Only after the first test was completed and the score sheets collected did subjects proceed to the retest (with a new, blank score sheet).

For each subject, we obtained: (1) a test score (test results compared to known criterion); (2) a retest score (how subjects scored against a known criterion when repeating the same test for a second time); (3) an average test-versus-retest score; and (4) a reliability score (for every decision, how consistently did each subject agree with herself or himself as they evaluated the same plants twice) (table 1).

TABLE 1. Job category, number of completed samples and reliability score between the test and retest

Position-ID #	Samples evaluated	Raw count error	Reliability	Test	Retest	Avg. test/ retest
	no.	*no. (%)*	....	%	....	
Sorter-1	150		84.00	62.00	55.33	58.67
Sorter-2*	149		67.11	76.51	53.33	64.92
Sorter-3*	150		84.67	62.00	70.67	66.33
Sorter-4*	128		52.54	53.49	81.88	67.69
Sorter-5	150		60.00	88.67	59.33	74.00
Sorter-6	150		86.00	76.00	72.67	74.33
Checker-7	150	33 (1.1)	86.67	80.00	73.33	76.67
Sorter-8	150		79.33	78.67	75.33	77.00
Sorter-9	150		84.00	82.67	73.33	78.00
Checker-10*	147	163 (5.6)	74.15	73.65	83.22	78.44
Sorter-11	150		90.67	80.67	80.67	80.67
Sorter-12	150		76.67	81.33	83.33	82.33
Sorter-13	150	15 (0.5)	90.67	82.00	83.33	82.67
Sorter-14*	148		82.88	85.23	84.35	84.79
Sorter-15	150		84.00	82.00	88.67	85.33
Sorter-16	150		84.00	84.67	86.00	85.33
Sorter-17	150		89.33	84.00	86.67	85.33
Sorter-18	150		86.67	85.33	85.33	85.33
Sorter-19	150		84.72	84.72	87.50	86.11
Counter-20	150	33 (1.1)	92.00	86.67	88.00	87.33
Super checker-21	150	44 (1.5)	84.00	92.67	84.67	88.67
Sorter-22	150		86.67	88.67	88.67	88.67
Counter- 23	150		86.67	88.00	90.67	89.33
Counter-24	150	32 (1.1)	90.67	88.67	90.00	89.33
Counter-25	150	57 (2.0)	90.67	93.33	89.33	91.33
Checker-26	150	12 (0.4)	90.67	92.00	90.67	91.33
Sorter-27	150		91.33	91.33	92.00	91.67
Counter-28*	146	37 (1.3)	94.44	90.41	94.59	92.50
Owner-29	150		91.33	94.00	92.00	93.00
Checker-30	150		94.67	94.00	94.00	94.00
Manager-31	150	20 (0.7)	96.00	96.00	94.67	95.33

* Subjects did not complete the reasons for rejecting plants.

The average test/retest scores ranged from a high of 95.3% (excellent by any standard) to a low of 58.7%. Had the low-scoring subject indiscriminately accepted all plants for packing without rejecting any, she would have scored better (60%). In fact, it was much more common for subjects to reject good plants than to pack bad ones. Campbell and Madden (1990) also found that experienced raters tended to overestimate plant disease incidence. Our results are similar to those of the medical decision-making study (Mcquillian 2001), in terms of finding a large variation between the best and worst rater in the group.

As test scores increased, reliability scores generally increased as well. Low reliability scores (i.e., assigning different quality scores to the same plants) mean that a subject does not see quality issues consistently. It is possible for individuals to have high reliability scores, yet do poorly in the test/retest. Such individuals may have a reliable eye for quality, but be calibrated to a different north.

We told prospective study participants that they must be able to read and write, but nonetheless had one subject who could not fill out the score sheet. Perhaps this individual felt trapped into making a face-saving move, or else wanted the hourly wage that the grower paid to study participants.

Of the remaining 31 subjects, six turned in partial results. They recorded retain-versus-reject decisions, but not reject reasons. These six ranged from the second lowest score to the fourth highest of all participants in terms of their average test/retest scores (table 1).

Identifying discard reasons. As long as sorters understand quality parameters, it is not essential that they (1) can explain it, or (2) can read or write. In contrast, quality-control personnel must be able to do both. The remaining 25 subjects (23 female, two male) completed the final portion of the study, where the reasons for rejecting plants were incorporated into retain-versus-reject decisions. Average test/retest scores ranged from a low of 40% to a high of 92% (table 2).

Subjects who scored highly in the test/retest also tended to have higher reliability scores. Some of the quality-control personnel did quite poorly in this test, with the super checker doing worse than both the checkers and counters she was supposed to direct. Several checkers and counters showed great potential for a super-checker position and were likely to improve with additional training.

As expected, we found high variability among subjects in terms of consistently being able to count plants, make retain-versus-reject decisions and determine the reason for rejecting plants. This variability existed among subjects who were already employed and supposedly knowledgeable. Had we administered the tests to applicants unfamiliar with the industry, we would expect to see even greater variability.

Job samples for testing employees

Our tests involved straightforward, objective issues (such as counting), as well as more subjective questions (such as whether a strawberry plant has sufficient root hairs). We found that subjects who did well in one test did not necessarily do well on another. Consequently, employers should also consider the use of tests to make placement decisions.

Selection procedures for particular tasks vary widely in terms of how valid they are. Validity, in the context of employment testing and placement, deals with how well an instrument or test predicts on-the-job behavior. Intelligence and personality tests are of limited value for predicting job performance, while job samples are highly valid predictors.

A job sample involves asking subjects to perform portions of the actual job duties. Examples may include picking oranges, pruning a deciduous orchard, driving a tractor or treating a calf. Agriculture lends itself well to job sample testing. Farm employers can set up several stations with different job duties to test and evaluate (Billikopf 2003).

It is important to test for as many different types of job tasks as the person will perform on the job. Such practical tests can be easily submitted to content oriented validity and in some instances may also be validated through a criterion-oriented approach (Anastasi 1982; Billikopf 1988, 2003; Federal Register 1978; US Department of Labor 1999). Tests can be designed so that subjects need not be able to read or write. The individualized nature of these tests can make them more time-consuming, however.

The most common error in the reject-versus-retain test was discarding good plants. A combination of preselection testing and careful placement, as well as the use of testing as a performance evaluation and training tool, should reduce material waste and at the same time increase worker wages by a considerable percentage (such as when workers get paid for plants they were previously discarding). Without testing, management mistakes could lead to, for example, placing a super checker in a position of responsibility (such as training and evaluating) over more-skilled individuals.

The objective of this study was to warn researchers involved in subjective evaluations, as well as farm employers whose personnel must evaluate quality on-the-job, that quality determinations should not be taken for granted. Even though the study was carried out in a specific industry, almost every agricultural industry should pay more careful attention to quality.

TABLE 2. Reliability, average test/retest score, test score and retest score for retain-versus-reject test*

Position-ID #	Reliability	Reject-reason reliability	Avg. test/retest	With reject reason: Avg. test/retest	Test	Retest
	%					
Sorter-1	84.00	38.67	58.67	40.00	42.00	38.00
Sorter-11	90.67	68.00	80.67	58.00	54.00	62.00
Sorter-5	60.00	60.00	74.00	61.67	64.00	59.33
Sorter-6	86.00	63.33	74.33	62.67	63.33	62.00
Sorter-9	84.00	62.67	78.00	63.67	68.00	59.33
Sorter-8	79.33	65.33	77.00	64.00	64.67	63.33
Sorter-12	76.67	57.33	82.33	64.33	57.33	71.33
Super checker-21	84.00	59.33	88.67	67.33	68.67	66.00
Checker-7	86.67	70.00	76.67	68.67	70.00	67.33
Sorter-15	84.00	65.33	85.33	69.67	65.33	74.00
Counter-23	86.67	78.00	89.33	72.67	72.00	73.33
Sorter-18	86.67	70.00	85.33	74.00	77.33	70.67
Sorter-16	84.00	76.00	85.33	74.33	76.00	72.67
Sorter-22	86.67	74.67	88.67	74.67	73.33	76.00
Sorter-27	91.33	82.67	91.67	75.33	74.67	76.00
Sorter-17	89.33	82.00	85.33	75.67	72.67	78.67
Sorter-19	84.72	69.44	86.11	77.43	71.53	83.33
Sorter-13	90.67	86.00	82.67	78.33	78.67	78.00
Counter-24	90.67	78.67	89.33	78.67	78.67	78.67
Counter-20	92.00	80.67	87.33	80.67	80.00	81.33
Checker-26	90.67	80.00	91.33	82.00	78.67	85.33
Counter-25	90.67	80.00	91.33	82.67	84.67	80.67
Checker-30	94.67	86.00	94.00	84.67	84.00	85.33
Owner-29	91.33	84.00	93.00	89.67	88.67	90.67
Manager-31	96.00	92.00	95.33	92.00	92.00	92.00

*Test and retest scores are measures of how well subjects did when contrasted against known correct answers.

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RESEARCH ARTICLE

California teachers support the Nutrition Competencies — new nutrition instruction guidelines

by Nadine Kirkpatrick, Marilyn Briggs
and Sheri Zidenberg-Cherr

Our research group reviewed, updated and field-tested "Nutrition Competencies for California's Children, Pre-Kindergarten through Grade 12," a document that provides comprehensive and sequential nutrition goals for students. The review process included: (1) comparative analysis with state and national nutrition and health documents; (2) professional input by UC nutrition and education faculty and California Department of Education nutrition staff; (3) review by national, state and local experts in nutrition, education and food service; and (4) field review by and a survey of California public school teachers. The teachers that we surveyed overwhelmingly agreed that the final Nutrition Competencies document was age- and academically appropriate for students in their grade levels. More than 81% found the Nutrition Competencies document well-structured and user-friendly. The teachers supported its inclusion in the school curriculum, and requested additional support materials such as lesson plans in order to incorporate nutrition lessons into the core subject areas.

Michael Bush

The California Department of Education is in the process of finalizing new guidelines — called the Nutrition Competencies — for educating school-age children about healthy eating and nutrition. In a supervised classroom activity at John Muir Elementary School in Berkeley, 2nd graders Francine and Maraya stir freshly harvested fall vegetables.

Over the past two decades, the prevalence of overweight children (ages 6 to 11) in the United States more than doubled (DHS 2004; CDC 2005). Among adolescents (ages 12 to 19), the prevalence more than tripled from 5% in 1980 to 16% in 2002. One in three children and one in four adolescents are either overweight or at risk of becoming overweight (DHS 2004). In California, more than a quarter of K-12 students are overweight and nearly two-fifths are considered unfit. Among the affected students, black and Latino youths face higher rates of overweight and lower levels of fitness than white and Asian youths (DHS 2004).

The increase in overweight and related health problems — such as type II diabetes, high blood pressure, high cholesterol and orthopedic problems — observed in children over the last two decades supports the need for school-based nutrition education. Specifically, it has become increasingly clear that there is a need to provide children with the knowledge and tools to choose a healthy diet and lifestyle.

Comprehensive, school-based nutrition education programs could help to decrease the incidence of overweight and obesity, as well as related chronic diseases such as diabetes and heart disease among Americans (Hoelscher et al. 2002; Anonymous 1997; Olson et al. 1993; Mackie and Oickle 1997). Children are at lower risk of developing such chronic diseases later in life when they are exposed early to nutrition education, including how to cope with stress and the benefits of a balanced diet, regular exercise and not smoking (Perez-Rodrigo and Aranceta 2001).

School is an ideal environment for implementing nutrition education in a systematic and efficient manner, not only for students but also for teachers, food service and other school staff, parents and community members (Lavin et al. 1992; Nicklas et al. 1997; Briggs et al.

The Nutrition Competencies incorporate farm-to-fork nutrition-education strategies for all grade levels (K-12). At Rock Creek Elementary School in Auburn, kindergarten students tend their garden.

Glossary

Bloom's taxonomy: A taxonomy used specifically in education, particularly in creating standards and learning goals. It categorizes the stages of learning: knowledge, comprehension, application, analysis, synthesis and evaluation.

Competency: Acquiring knowledge about, as well as learning skills and becoming proficient in a certain area — in this case, nutrition.

Content standard: Adopted by the California State Board of Education to define what students are expected to know about various school subject areas at each grade level.

Overweight: Children with a body mass index (BMI = kg/m^2) at or above the 95th percentile of a sex-specific BMI growth chart (DHS 2004). (The Centers for Disease Control and Prevention avoids labeling children as "obese.")

Self-efficacy: The belief that you are competent in what you are doing. Teachers must feel that they have a grasp on the subject material in order to be comfortable teaching it. Self-efficacy can be boosted through short, regular workshops and meetings with other teachers trying to integrate nutrition into the school curriculum.

Unfit: Students who are not able to meet the minimum performance requirements in the following six areas of California physical fitness testing: aerobic capacity, body composition, abdominal strength, upper-body strength, trunk strength and flexibility.

2003; Perez-Rodrigo and Aranceta 2001; Summerfield 1995; Sunseri et al. 1984). Lavin et al. (1992) stated that "schools are society's vehicle for providing young people with the tools for successful adulthood." Having the knowledge and ability to make healthful dietary and lifestyle decisions should be prominent in such a "toolbox."

School wellness policies

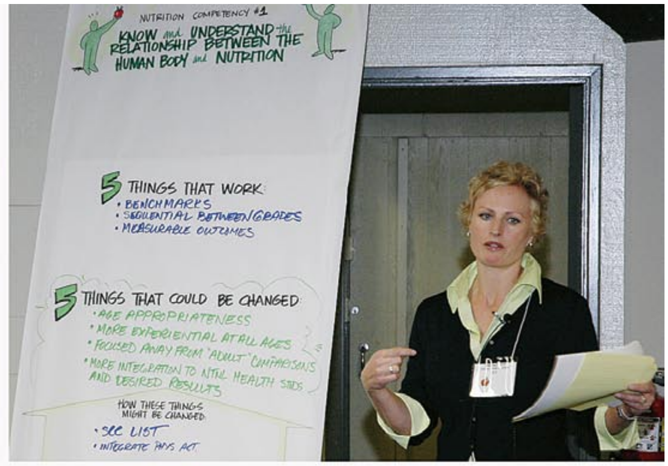
At the national level, the importance of comprehensive, school-based nutrition education programs (Stang and Bayerl 2003) has been exemplified by the Child Nutrition and Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) Reauthorization Act of 2004 (Pilant and ADA 2006). This law requires that every school district participating in the national school lunch or school breakfast programs develop a local wellness policy by the beginning of the 2006-2007 school year. These policies must: (1) include nutrition guidelines for all foods sold on school campuses throughout the school day; (2) include goals for nutrition education, physical activity and other school-based activities that are designed to promote student wellness; (3) establish a plan for implementation of the policy, including designating one or more persons within the local educational agency or at each school to be responsible for compliance; and (4) be developed by parents, students, food service staff, the school board, school administrators and the public.

In preparing these new wellness policies, districts throughout California must consider what to base them on and which goals for nutrition education to address. Although the California State Board of Education has adopted content standards for core subject areas such as English-language arts, mathematics, history-social science and science, no such content standards exist for nutrition (CDE 1997a, 1997b, 1998b, 1998c).

The Nutrition Competencies

Because there are no state nutrition standards to fill this gap, our major objective was to produce the "Nutrition Competencies for California's Children,

In January 2005, a broad range of stakeholders met in Davis to evaluate a new draft of the Nutrition Competencies document. A small group reviewed the third competency, on food choices.



The seven competencies include understanding nutrition recommendations, identifying where foods come from, and handling and preparing food safely. *Above*, Jamie Buffington, nutrition education chair of the Davis Farm-to-School Connection.

Nutrition Competencies for California's Children, Pre-Kindergarten through Grade 12

I. Know and understand the relationship between the human body and nutrition.
II. Know current nutrition recommendations and how to apply them.
III. Identify and explore factors influencing food choices.
IV. Identify foods that come from particular regions and understand the factors (local, regional, statewide, national and global) that influence food availability, production and consumption.
V. Demonstrate proper food handling and storage to maximize the nutritional quality of food and personal hygiene to prevent foodborne illness.
VI. Identify valid nutrition information, and advocate for policy.
VII. Identify the variety of food-related careers.

Pre-Kindergarten through Grade 12" document, to provide comprehensive and sequential nutrition goals for students. Standards for nutrition education in California schools were first developed as part of the California Department of Education's (CDE) "Choose Well Be Well" documents (CDE 1982a, 1982b; CDE 1984a, 1984b). Based on the minimum proficiencies for nutrition in these documents, the CDE Nutrition Services Division created an initial draft of the Nutrition Competencies document (CDE 2001). Teachers, curriculum specialists, child nutrition program and food service professionals, and nutrition education specialists contributed to this process. The 10 competencies in the 2001 draft version included understanding and applying the Food Guide Pyramid, demonstrating safe food handling and personal hygiene, identifying the factors influencing food intake, explaining nutritional needs and how to access scientifically valid nutrition information, and maintaining a healthy body and positive body image.

Our research group developed and implemented a sequential review process to align the draft Nutrition Competencies document with state and national nutrition and health documents; California content standards for science, history-social science, English-language arts, mathematics and physical education (CDE 2005); and expectations of the "Health Framework for California Public Schools" (CDE 2003). The California State Board of Education adopted the Health Framework in 2002; it provides a framework for K-12 health education with a focus on safety, violence and other health topics. It is not required in schools, but has played a role in creating California's new mandated "Health Education Content Standards" for schools, expected to be available in 2007. Since nutrition is also in the Health Education Standards, it was important to ensure that the revised Nutrition Competencies emphasized similar nutrition learning goals.

Updating and field-testing

The purpose of this paper is to describe the development of the updated Nutrition Competencies document and how field-testing was used to fine-tune the competencies. Another goal was to determine the overall acceptance of the Nutrition Competencies document among participating California public school teachers. We followed a six-part process to review the Nutrition Competencies.

(1) Comparative analysis. Comparative analysis was conducted to review and analyze related guidelines and standards, including the original 2001 CDE Nutrition Competencies document, in order to develop a new Nutrition Competencies document containing appropriate grade-level expectations and key nutrition topics compliant with these documents (JCNHES 1995; CCSSO 1998; CDE 1998a). Grade-level expectations are "statement(s) that define what all students should know and be able to do at the end of a given grade level" (LDE 2004).

The major outcome of the comparative analysis was that the Nutrition Competencies were narrowed down from 10 to seven "competencies" (see box). The first step in streamlining the competencies was to code each of the original 10 competencies according to thematic concepts. The common themes noted included: dietary guidelines, serving sizes, nutrient types and functions, making healthy food choices, proper food handling, assessing nutritional needs, finding valid nutrition information and food-related careers. In addition, we added themes to the updated Nutrition Competencies, such as human physiology, nutritional needs at different life stages, developing decision-making skills and nutritional supplements.

(2) Linkage to state core-subject standards. The Nutrition Competencies document was also expanded to identify links between grade-level expectations and standards adopted by the State Board of Education for physical education and the core subjects of English-language arts, mathematics, history-social science and science.

(3) Professional input. The updated Nutrition Competencies document was then sent out for review to UC nutrition and education faculty, and CDE nutrition staff. As a result, individual grade-level expectations were reworded to be more specific, some were moved to different subheadings or competencies, and the order of the seven competencies was modified. Among the themes added to the document were: emphasizing healthy foods, defining foodborne illness and understanding how foodborne illnesses are contracted.

(4) Expert panel. Next, we facilitated a review of the revised document by a panel of expert stakeholders. This panel consisted of 50 professionals including nutrition and education faculty, UC Cooperative Extension advisors and additional agriculture representatives, public school and pre-kindergarten teachers, principals, health and education government agency staff, and food service representatives.

As a result of the expert panel review, additional changes were made to the Nutrition Competencies document. The panel members encouraged linking the document to the expectations of the "Health Framework for California Public Schools: Kindergarten Through Grade Twelve" (CDE 2003), as well as to the academic California content standards for the core subjects and physical education. The language of the grade-level expectations was changed to reflect Bloom's Taxonomy, emphasizing the sequential organization of the document. In addition, themes were added such as the relationship between nutrition and physical activity, food handling from farm to table, kitchen safety and the food web (producers, consumers and decomposers).

Following incorporation of comments from the expert panel meeting, members of the CDE Internal Review Team provided further input and appropriate changes were made, resulting in an updated document that was ready for field-testing. The new 14-page Nutrition Competencies document now contained seven competencies, with expectations for each competency in each of five grade clusters: pre-kindergarten/kindergarten, lower elementary school (grades 1 to 3), upper elementary school (grades 4 and 5), middle school (grades 6 to 8) and high school (grades 9 to 12). (The Nutrition Competencies includes learning goals for pre-kindergarten, and we surveyed a small sample of pre-K teachers. However, the sample was too small to include in this manuscript, so our survey emphasized kindergarten through grade 12 teachers.)

(5) Teacher survey. The primary goal of administering this survey was to obtain feedback from teachers on the utility of the Nutrition Competencies for classroom instruction. Additional purposes of the survey were to compare teacher responses (1) among different grade levels, (2) from schools with and without a history of nutrition education programs and (3) from low-income and not-low-income schools.

A survey was developed to capture teachers' opinions regarding the updated Nutrition Competencies document in six major subject areas: (1) its perceived value, (2) barriers and limitations to its use in preparing nutrition lessons, (3) scope and sequence, (4) age-appropriateness of the grade-cluster expectations, (5) appropriateness of links to the expectations of the "Health Framework for California Public Schools: Kindergarten Through

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UC nutrition educators plan to use the Nutrition Competencies to develop materials for school-based nutrition education and to better integrate nutrition into the school curriculum. Daymon (left) and Jack, 4th graders at John Muir Elementary School in Berkeley, team up for close plant observation under a sage bush.

Grade Twelve," as well as to California content standards for the core subjects and physical education, and (6) general attitude toward and experience with nutrition education in the classroom.

(6) Field-testing. This survey was pilot-tested on 26 teachers in seven Petaluma City schools to assess its content validity and clarity. The participating schools were later excluded from the California teacher survey sample.

We recruited 250 California public school teachers to participate in the California Teacher Survey. The sample included one teacher per school, and was stratified on multiple levels. First, the sample was stratified by grade-level cluster, with 30 kindergarten, 60 lower elementary, 60 upper elementary, 50 middle school, and 50 high school teachers.

In addition, the kindergarten, 2nd grade and 5th grade schools were stratified according to whether or not they participated in SHAPE (Shaping Health as Partners in Education), a network of more than 90 California school districts working to improve the health and academic success of California children by providing consistent nutrition messages in child nutrition programs, classrooms and throughout the school environment (CDE 2006). (Elementary school districts mainly use this program, but it is meant for K-12 education.) Finally, the sample was also stratified by income level of the school. An analysis of the association between SHAPE and income on survey response will be discussed elsewhere (manuscript in review).

Middle schools (7th grade) and high schools (10th grade) were stratified by subject areas. Equal numbers of teachers were recruited from the subject areas of English-language arts, health (including both physical education and home economics), history-social science, math and science. In addition, the sample of middle schools and high schools was further stratified by income.

Charter, juvenile hall, continuation and special education schools were eliminated from the sample pool. The schools were numbered and the sample was randomly drawn out of the sample pool. Eligible schools were contacted via phone, and the principals at these schools selected teachers for participation. Overall, 632 schools were contacted; final participation was 250. A total of 217 questionnaires were completed and returned via U.S. mail, resulting in an 86.8% response rate.

Statistical analysis. The survey data were analyzed with the Statistical Package for the Social Sciences for Windows (SPSS Inc., ver. 13.0, Chicago, Ill., 2004). Descriptive statistics were calculated for all survey questions. Missing data and "not applicable" responses were excluded from all analyses. Chi-square tests and analysis of variance (ANOVA) were conducted to detect any differences in teacher responses by grade level. A significance level of $P \leq 0.05$ was set a priori. Follow-up tests to the ANOVA analyses were performed using the Tukey post-hoc test at a 5% procedure-wise error rate. Chi-square tests were adjusted for multiple comparisons using Bonferroni techniques in order to have a 5% procedure-wise Type I error rate for each dependent variable. Here, for each post-hoc test conducted, $P \leq 0.05/3 = 0.0167$ was considered to be statistically significant.

TABLE 1: Mean score of California public school teachers rating the developmental appropriateness of the individual nutrition competencies*

Competency	Grade-level cluster†	Responses (no.)	Mean‡	Std. dev.
I	ES (K–5)	136	4.3a	0.8
	MS (6–8)	39	4.7a	0.7
	HS (9–12)	42	4.2a	0.9
II	ES (K–5)	135	4.0a	1.0
	MS (6–8)	39	4.2ab	0.9
	HS (9–12)	41	4.4b	0.9
III	ES (K–5)	136	4.1a	0.9
	MS (6–8)	39	4.2a	0.7
	HS (9–12)	41	4.3a	0.9
IV	ES (K–5)	132	3.2a	1.2
	MS (6–8)	38	3.8b	0.9
	HS (9–12)	41	4.1b	1.1
V	ES (K–5)	136	3.7a	1.1
	MS (6–8)	39	3.6a	1.1
	HS (9–12)	41	4.0a	1.1
VI	ES (K–5)	136	3.8a	1.0
	MS (6–8)	39	4.1a	0.9
	HS (9–12)	41	4.2a	1.0
VII	ES (K–5)	136	3.6a	1.4
	MS (6–8)	38	3.7a	0.9
	HS (9–12)	40	3.9a	1.2

* Teachers responded on a five-point Likert scale with 1 = do not agree and 5 = strongly agree.
† ES = elementary school; MS = middle school; HS = high school.
‡ Within each competency, means followed by same letters do not differ significantly from one another at the 0.05 level of significance (Tukey post-hoc test).

California teacher survey

Perceived value. The majority of teachers surveyed agreed that the Nutrition Competencies document had value to them as teachers (more than 92%) and to their students (more than 97%). All of the kindergarten through 5th-grade (elementary school) teachers agreed that the Nutrition Competencies had value to them, whereas 92.3% of high school teachers agreed. A chi-square follow-up test, adjusted for multiple comparison, showed that the difference between elementary and high school teachers is significant ($P = 0.012$). This result indicates that elementary school teachers are more willing to embrace a document like the Nutrition Competencies in their curricula, while high school teachers may be hesitant because they are preoccupied with preparing students for testing.

Overall acceptance. A majority of teachers agreed or strongly agreed (72.9%) that they would use the Nutrition Competencies to plan nutrition lessons for their students. There were no significant differences among teachers from the different grade clusters.

Age-appropriateness. More than 93% of teachers said that the Nutrition Competencies document was age-appropriate for the grade level that they teach. There were no significant differences among teachers from the different grade clusters.

Teachers often mentioned that the rising number of overweight students motivates them to teach nutrition in their classrooms.

The teachers also rated the age-appropriateness of the seven individual nutrition competencies on a scale ranging from "do not agree" to "strongly agree." When comparing the responses of teachers by the grade cluster in which they teach (elementary, middle or high school), most agreed or strongly agreed that Competency I (more than 83%) and Competency II (more than 72%) were appropriate. Significant differences were found in how teachers rated Competency II: more high school teachers (88%) agreed or strongly agreed that Competency II was age-appropriate than did teachers from the elementary school grade cluster (73%; $P = 0.028$) (table 1).

The majority of teachers from these three grade clusters agreed or strongly agreed that Competency III (more than 80%), Competencies V and VI (more than 60%) and Competency VII (more than 58%) were age-appropriate. ANOVA with a Tukey post-hoc test showed significant differences in how teachers rated the age-appropriateness of Competency IV: a higher percentage of middle school (58%; $P = 0.027$) and high school (76%; $P = 0.001$) teachers agreed or strongly agreed that Competency IV was age-appropriate than did teachers from the elementary school cluster (47%) (table 1).

Scope and sequence. A considerable percentage of teachers in all grade clusters (more than 81%) found the Nutrition Competencies document well-structured and user-friendly. Most teachers (more than 81%) agreed that the document is sequential within each grade cluster, meaning that the presented concepts build on each other and can be taught in order. This is important when putting together learning goals or standards for any subject area, to keep students on track and build on their previous knowledge. A high percentage of all teachers (more than 89%) also agreed that the document's grade-level expectations within each grade cluster were sequentially organized.

Teacher suggestions

Several teachers provided suggestions for improving the Nutrition Competencies document in the qualitative portion of the survey. Their comments were coded and sorted into categories.

Several teachers had suggestions and concerns regarding lesson plans. Sample lesson plans and curricula, particularly integrated ones, were the most requested items. An integrated lesson plan would connect the learning goals of the Nutrition Competencies with specific California academic core subject standards (that the teachers have to address) and give them a detailed lesson plan that includes possible activities, homework and so on. The other items requested were materials, resources, supplies, teacher training and integrated textbooks.

The challenge of time constraints for integrating nutrition into the school curriculum was commonly mentioned. Many teachers suggested that the Nutrition Competencies be incorporated into what they already teach, due to the lack of time during the regular school day to make nutrition a separate subject.

Some teachers suggested making nutrition an elective class in middle and high school, or incorporating nutrition into health or physical education classes. It was also suggested that nutrition concepts be made a requirement and part of California state testing.

In addition, it was noted that foods available on school campuses should reflect what students learn in class. Finally, teachers had concerns about the potential lack of support regarding nutrition education from administrators. Many did not think administrators would fully support teachers who wanted to integrate nutrition lessons into their classes and curriculum; they thought they would not have sufficient time and monetary support to plan nutrition lessons, which would result in very few teaching materials available to actually put lessons together.

School-based nutrition education

The teacher survey was the concluding step in the systematic review process and contributed to producing the final updated "Nutrition Competencies for California Children, Pre-Kindergarten through Grade 12." We found that California public school teachers from all grade levels supported the incorporation of the Nutrition Competencies into the school curriculum.

Teachers strongly agreed that there is a need for the Nutrition Competencies and often mentioned that the rising number of overweight students motivates them to teach nutrition in their classrooms. "I think the Nutrition Competencies are well done, and certainly something much needed in society today. I also like the way it is taught all through the school years. The lessons should span 10 weeks or more, week after week, year after year," one teacher explained.

Future directions of research should include conducting focus groups with teachers from all grade levels to improve the links between the Nutrition Competencies document and California content standards for the core subjects and physical education. One teacher wrote: "This provides a wealth of information for students to become more nutritionally aware [and] intelligent. I see teachers being more apt to include this curriculum if it is integrated with their current curriculum/standards-based lessons, which, in kindergarten, was included very well." Another teacher noted: "The best way to make sure that nutrition is being taught is to give single-subject teachers lesson plans that are standards-based (they already have to teach them) but infused with the nutritional curriculum. Time is so precious most teachers can't/won't find the time to include nutrition lessons unless you show them how."

The results of this study have implications for the application, implementation and success of the Nutrition Competencies. Teachers need to be provided with appropriate resource materials and training to develop self-efficacy when teaching nutrition in the classroom. The written feedback from teachers participating in the survey also implies that teaching children and young adults about nutrition cannot be the sole responsibility of teachers. School-based nutrition education requires a sequential and comprehensive framework that helps teachers to plan their lessons. In addition, to ensure that schoolwide nutrition policies are

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Teachers from across the state were surveyed to assess the final 14-page Nutrition Competencies document, including its perceived value to them and its age-appropriateness for particular grade levels. At John Muir Elementary School in Berkeley, "chef Carrie" made pickles with 4th and 5th graders (left to right) Jalaya, Naomi, Naila and Kayla.

in place, there must be coordination with food service staff, family and other members of the community, as well as school administrators (Auld 1998).

The Nutrition Competencies document has undergone a few more revisions since our research group presented CDE with our "final version"; it is not yet required in schools and will take some time until we see it in the classroom. The UC Davis Department of Nutrition plans to post the Nutrition Competencies to the Internet (http://nutrition.ucdavis.edu) and to use the document as a basis for providing additional school-based nutrition education support. Our survey showed that teachers recognize the need for incorporating nutrition into the school curriculum. As more support materials become available, they will have the resources they need for incorporating nutrition lessons into their daily school curriculum.

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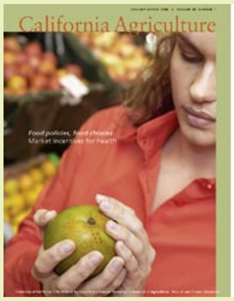

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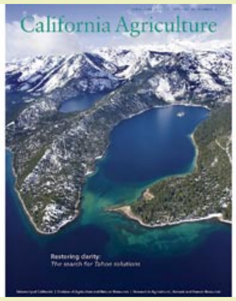

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Sokolow AD, Grossi RE, Kawamura AG, Sumner DA. Panel debates next Farm Bill's impact on California. Cal Ag 60(1):5–7. **FP**

Research updates

Research seeks to adapt conservation tillage for California fields. Cal Ag 60(3):112–3. **CT**

UC's Sagehen reserve is California's newest experimental forest. Cal Ag 60(2):47–8. **LT**

UC works to monitor, prevent, contain avian flu. Cal Ag 60(3):110–2.

Weed control helps prevent erosion into Lake Tahoe. Cal Ag 60(2):48. **LT**

Special coverage

30 years ago in *California Agriculture*. Cal Ag 60(4):216. **CA**

40 years ago in *California Agriculture*. Cal Ag 60(3):168. **CA**

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Celebrating a work in progress: UC journal delivers research to Golden State and beyond. Cal Ag 60(4):174–5. **CA**

Citrus Research Center–Agricultural Experiment Station; UC Riverside marks a century of agricultural innovation — still thriving in an urban empire. Cal Ag 60(4):176–9.

Information for Contributors. Cal Ag 60(3):166–7.

COMINGUP

A glyphosate-resistant horseweed plant shows regrowth of new tissue 3 to 4 weeks after a glyphosate application.

Assessing transgenic insects, "pharma" crops and herbicide-resistant weeds

Transgenic crops are now common in U.S. row crops such as corn, soybeans and cotton. However, perceived risks and regulatory concerns have limited the spread of biotechnology to other agricultural realms. A previous issue of *California Agriculture* (July-September 2006) examined the risks and benefits of genetic engineering in California-grown crops (gene flow), aquaculture and livestock. In the next issue, scientists review the current technical, regulatory and commercial issues surrounding transgenic insects and pharmaceutical crops, and report on glyphosate-resistant horseweed in the San Joaquin Valley.

Also:

Folate intake among low-income women

Mineral balances in dairy

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