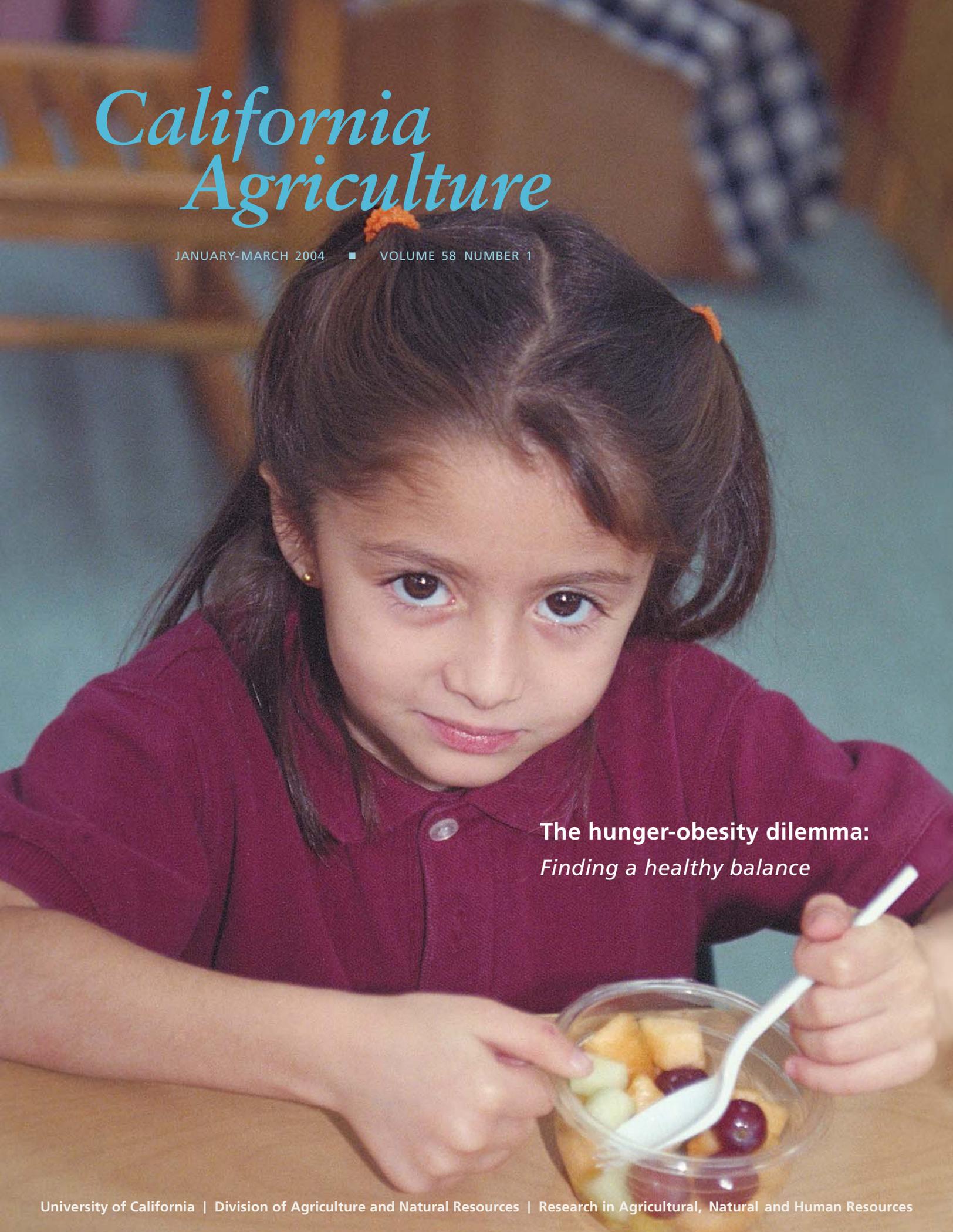


California Agriculture

JANUARY-MARCH 2004 ■ VOLUME 58 NUMBER 1



The hunger-obesity dilemma:
Finding a healthy balance

California's growing diversity drives profound change



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

As the 2000 census confirmed, California has become a multicultural society with no single ethnic majority. Today, our 35.5 million diverse citizens are 46% non-Latino white, 35% Latino, 12% Asian and 6% black. This historic shift is the leading edge of a massive demographic change. By 2030, Latinos are projected to make up almost 44% of California's population — 22.6 million people. Asians and Latinos together will comprise more than two-thirds of the state's citizens.

The dramatic and continuous growth of Latinos and other ethnic groups (see *California Agriculture*, January-February 2000) means that UC's Division of Agriculture and Natural Resources (ANR) needs to develop new and more effective ways to reach its diverse clientele. Fully 40% of Californians speak languages other than English at home; Spanish is our second most common language, used by 26%.

California's ethnically diverse groups may be new to the state and nation, and often have the most critical need for the information ANR has to offer. Our faculty, advisors and staff have the new challenge of delivering this research in ways that can be understood linguistically and culturally.

This issue of *California Agriculture* contains five articles that illustrate how ANR researchers and educators are serving a diversity of Californians. Researchers investigate Latino food insecurity (page 18), shed light on the puzzling coexistence of hunger and obesity (page 12), report on why a large number of eligible rural Latino families fail to claim the Earned Income Tax Credit (page 24), examine how Proposition 10 funds are distributed to improve the health and education of preschool children (page 27) and analyze farmworker employment patterns statewide (page 35).

These studies represent but a small fraction of efforts under way to extend UC research results to Californians in every corner of the state. ANR information spans the full range of agricultural, natural and human resource issues facing the state, including nutrition, food safety, specialty crop production, water and soil conservation, pesticide handling, household budgeting, parenting — even responses to a natural disaster (page 6). It is delivered through Cooperative Extension county offices statewide.

Bilingual ANR researchers and educators help us better meet the needs of our diverse clientele. Today nearly 60 Cooperative Extension advisors (about one in four) speak Spanish fluently, and more than 40 county offices have at least one advisor or staff person who speaks Spanish. Virtually every major program in ANR now has materials available in Spanish, as well as Hmong, Laotian, Vietnamese and Japanese. Other statewide efforts include:

Pesticide safety. Since 1992, the IPM Pesticide Safety Education program has conducted nearly 300 workshops to train and certify more than 4,800 instructors in the safe use

of pesticides. These instructors in turn have trained over 870,000 farmworkers, growers and pesticide handlers, most of them Spanish-speaking, in pesticide handling, interpretation of label information and field application. The bilingual *Illustrated Guide to Pesticide Safety/Guía Ilustrada para el Uso Seguro de Pesticidas* has sold more than 100,000 copies.

Multilingual outreach. ANR's Spanish Broadcast and Media Services and Communication Services help extend science-based information to clientele in Spanish and other languages through translation services, news releases, radio feeds and preparation of reports and other publications.

Small farms. The UC Small Farm Program has six bilingual farm advisors working with growers in Spanish, English and Southeast Asian languages. Conferences and field days have been conducted entirely in Spanish, and many written materials, compact disks and audiotapes on specialty crops, production and marketing practices, are available in Spanish and other languages. Pesticide safety manuals have also been translated into Korean and Ilocano.

Farm safety. The Farm Safety program and the UC Agricultural Ergonomics Research Center develop innovative practices and equipment to reduce the historically high rates of farm injuries. The program produces educational materials in Spanish and English on ergonomic risk factors, develops specific interventions, demonstrates them and trains workers in the field. One such intervention involved the development of reduced tub sizes for wine-grape harvest, leading to a five-fold reduction in reported back pain without reducing productivity on farms adopting their use.

Nutrition education. The Food Stamp Nutrition Education Program (FSNEP) and the Expanded Food and Nutrition Education Program managed by ANR help clients to make more informed food-buying decisions and to be smarter consumers. The FSNEP program of California provided nutrition education to 127,800 families in 2002–2003; of these, 44.6% were Latino.

Accomplishments like these were considered innovative and groundbreaking 10 years ago; today they are the expectation. The Division strives to keep current, even one step ahead, of the educational and technical assistance needs of California's multicultural society. We have been successful because our scientists, advisors and staff are trusted sources of unbiased, research-based information, and because we are organized to deliver research results and practical information to stakeholders in every community in the state. No other UC program can make this claim.

However, the current budget crisis, and deep funding cuts to UC Cooperative Extension and the Agricultural Experiment Station, present serious challenges for the future.

These and other programs enable the University to meet a vital land-grant responsibility. They address the diverse needs of Californians, providing them with science-based knowledge for the safe and viable production of food, forests and fiber, and augmenting the health, economy and environmental well-being of the state.



California Agriculture

News and Peer-reviewed Research published by the Division of Agriculture and Natural Resources, University of California
VOLUME 58, NUMBER 1

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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 be accompanied by payment. Payment may be 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.

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COVER: Food insecurity and overweight coexist at high rates among low-income populations, for complex reasons (see page 12). UC nutrition educators are working to promote healthy food choices and lifestyle changes among children and adults. *Photo by Ken Hammond, USDA*



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Editor's note: Due to cutbacks related to the state's budget deficit, *California Agriculture* will be publishing four issues in 2004 instead of six.

Letters

PD-resistant rootstocks

In "Insecticide treatments disinfest nursery citrus of glassy-winged sharpshooter" (October-December 2003, p. 128-31), the authors state that there are no resistant rootstocks to Pierce's disease (PD). This is incorrect. There are actually a number of PD-resistant rootstocks. While none of them ameliorates the effects of *Xylella fastidiosa* in susceptible scions grafted to them, this omission implies that the grape industry is without options in development of new cultivars that are resistant to PD. Historically, there were grape-breeding programs in the South within the range of PD at the University of Florida and at the U.S. Department of Agriculture station in Meridian, Miss. Both of these programs



The glassy-winged sharpshooter

developed grape cultivars that are resistant to PD and long-lived under high PD pressure. Hopefully, with time, breeders in California will develop high quality, PD-resistant scions and rootstocks that will give California grape growers options in areas with glassy-winged sharpshooter infestations.

Tim Bourne, grape breeder
Visalia

Editor's note: As the writer points out, while PD-resistant rootstocks have been developed, none confer resistance to grafted breeds (scions) and there are currently no commercially available, effective breeds for grape growers to ward off Pierce's disease. UC scientists and others are studying the genetics of grapes, glassy-winged sharpshooter and the X. fastidiosa bacterium in an effort to develop disease-resistant varieties, in conjunction with an extensive classical breeding program (see July-September 2003, p. 69).

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 fl., Oakland, CA 94607. Include your full name and address. Letters may be edited for space and clarity.

Science briefs

Bush proposes immigration reform

On January 7, President Bush proposed a temporary worker program called Fair and Secure Immigration Reform, "to match willing foreign workers with willing U.S. employers, when no Americans can be found to fill the jobs." The proposal would grant legal status for 3 years to illegal workers in the United States, allowing them to travel back and forth to their home country without fear of being denied re-entry. "We must make our immigration laws more rational, more humane," Bush said.

UC Davis agricultural economist Philip Martin says the Bush proposal would allow U.S. employers to validate their past hiring of unauthorized workers and gain easier access to unskilled migrants from abroad, but would not provide migrants with a clear path to immigrant status and citizenship.

A study in this issue of *California Agriculture* reports that there are currently about 400,000 year-round equivalent jobs in California agriculture, which are

filled by an estimated 1.1 million workers (see page 35). Half of these workers are believed to be unauthorized.

"In California, self-employed unauthorized workers, such as those hired in day-labor markets and seasonally in agriculture, are presumably out of luck," Martin says. "They may find it hard to find employers who can provide credible employment histories."

Furthermore, Martin says, past experience with temporary worker programs — such as Braceros — in diverse governments and labor markets has shown that "nothing is more permanent than temporary workers."

Ecosystem approach for Klamath fish

Instead of focusing primarily on how water levels and flows affect endangered and threatened fish in the Klamath Basin, federal agencies charged with protecting the region's fish should pay greater attention to other causes of harm, says an October report from a National Research Council committee.

The committee included UC Davis professors Peter Moyle and Jeffrey Mount. Federal agencies cut off irrigation water to some Klamath Basin farmers in 2001 in an attempt to save endangered fish during a drought, igniting controversy over



At least half of California's agricultural workers are believed to be unauthorized.

the Endangered Species Act (see *California Agriculture*, July-August 2002).

The report covers an array of problems, such as excessive growth of algae and depleted oxygen levels in Upper Klamath Lake, dams that block spawning migrations, competition from hatchery fish, excessive sediment in streams, loss of stream bank vegetation and high water temperatures in the summer. It also emphasizes the need for a multispecies, or ecosystem, approach to management because there are several fish species in the basin that are declining.

"The main solutions for threatened salmon restoration lie in the tributaries, such as the Shasta River," says Moyle, an expert on native fish. "It once flowed all summer, with crystal-clear cold water, and had huge runs of coho and chinook salmon, and steelhead trout. If you reduced its use for irrigated pasture and alfalfa fields, that would lower its temperature. If you removed Dwinnell Dam, you'd increase access to habitat needed for spawning and for rearing of juveniles. This sort of ecosystem-level approach is what's needed in the Klamath Basin."

For more information, go to: www.nap.edu/catalog/10838.html.

Feed supplement produces heart-healthy milk

A new cattle-feed supplement that dramatically boosts the content of heart-healthy unsaturated fats in cows' milk has been developed by UC Davis researchers Moshe Rosenberg and Ed DePeters.

Milk, butter and meats contain high levels of saturated fats, which contribute to a higher risk of cardiovascular disease and high cholesterol in humans. Research over the years has focused on how to protect the unsaturated fats in vegetable-based feeds consumed by cows from being broken down by microorganisms in the cow's rumen and converted into saturated fats.

Unlike earlier methods, which involved unsavory chemical additives like formaldehyde and soap, the new supplement relies on proteins that occur naturally in milk and other foods. During feeding trials, the researchers mixed it with the cows' normal feed. Within less than 3 days, they recorded as much as an 800% increase in the proportion of specific unsaturated fatty acids, such as linolenic acid, in the cows' milk. The study involved more than 750 cow-days, with more than 1,500 milk samples analyzed.

Cows eat a variety of plant-based feeds (see page 54), including hay, corn, cotton seed and almond hulls, which contain vegetable oils that are naturally high in unsaturated fats. Announced in November, the new supplement allows these un-

saturated fats to pass unmodified through the rumen, the largest of four compartments in the cow's stomach.

Eventually, they enter the cow's intestine for digestion, where the unsaturated fatty acids are then available for absorption into the blood stream. Finally, the unsaturated fatty acids are presented to the mammary gland, where the milk is produced. (See page 59 for a study on the use of tomato pomace in chicken feed.)

Radar maps soil moisture to create better wine

Winemakers know that soil moisture is key to growing quality wine grapes, but accurately monitoring the soil's water content is a difficult and expensive task. Research led by UC Berkeley scientists is lending a high-tech hand to the fine art of grape growing by using ground penetrating radar, or GPR, to map soil moisture in vineyards.

"By providing detailed information about soil moisture, we can help viticulturists use water more efficiently," says UC Berkeley professor Yoram Rubin. "This has the potential to improve grape quality while reducing energy and water use."

GPR technology can also help reduce agricultural pollution and be used to scope out optimum plots of land for new vineyards. Where the soil is spatially uniform, vineyard managers could further refine the practice of matching grape variety to soil conditions. (See page 44 for research on the use of global positioning systems [GPS] to guide tractors.)

The delicate balance of soil moisture is important in creating smaller berries, which have a higher skin-to-juice ratio. With this higher ratio, the wine grape is more concentrated, ultimately leading to a finer wine.

The researchers use a vacuum cleaner-sized machine to skim the entire surface of the soil, sending electromagnetic pulses about 6 to 9 feet deep. Analysis of the GPR signals has allowed them to accurately estimate soil moisture to within 1% of true values.

For more information, go to: www.coe.berkeley.edu/labnotes/1003/rubin.html.



Professors Ed DePeters (left) and Moshe Rosenberg offer the feed supplement and hay to cows from the UC Davis dairy herd.

Debbie Altridge/UC Davis

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UC Davis hydrogeophysicist Susan Hubbard uses GPR to map soil moisture at the Robert Mondavi Winery.

Mike Kowalsky

Robert A. Eplett/OES CA

Toll-free number aids Spanish-speaking firestorm victims; UC reserve burns



The Cedar fire burned more than 280,000 acres and killed 14 people.

Staffer assists Latino victims

During a weekend of fires, Alberto Hauffen, a senior public information representative for UC's Spanish Broadcast and Media Services, anxiously watched flames approaching the East Highlands Ranch community in the San Bernardino Mountain foothills where he lives in with his wife and two children.

On Monday, Oct. 27, the fire was coming dangerously close to the Hauffen home, and people living two blocks north were ordered to evacuate. Fortunately, no houses were damaged and the fires were controlled by the next afternoon.

That evening, Hauffen went to a Red Cross shelter for evacuees in a hangar at the San Bernardino International Airport, which housed more than 900 people primarily from Big Bear, Arrowhead and other mountain communities.

"The Red Cross didn't have enough bilingual volunteers to assist non-English-speaking fire victims, so I offered to help," Hauffen says.

Hauffen spent several days helping Red Cross officials with interpreting and translating messages for evacuees, and conveyed announcements over the PA system.

Some Latino fire victims expressed despair after being told they had to supply a Social Security number among other documentation in order to qualify for fire relief, Hauffen notes, as many are undocumented immigrants.

"These families, in my opinion, will be hit the hardest, since they depend on low-income jobs in construction and service in restaurants and hotels. They do not own homes in those pricey resort communities, but they feared to have lost whatever they had," Hauffen recalls. "A single mother of four told me, 'Now I'm left as I came: no job, no home, nothing'."

Within days of the devastating fires that swept through Southern California in late October, UC Spanish Broadcast and Media Services (SBMS) gathered and adapted information for Spanish-speaking people and quickly distributed the phone number to UC Cooperative Extension county offices, the media and relief agencies.

A statewide toll-free number, called "AsisTel de la UC," had been announced Oct. 17 as part of a media campaign to provide Spanish-language materials for Diabetes Month in November. However, when the wildfires broke out, the phone number was quickly pressed into service to offer assistance to firestorm victims.

It now includes 31 concise messages in Spanish for dealing with the aftermath of wildfires, on topics ranging from completing insurance claims to the emotional well-being of adults and children.

"Many in the fire-ravaged communities are Latino immigrants, with limited information in Spanish to help guide their recovery," says Myriam Grajales-Hall, SBMS program manager based at UC Riverside. "We hope these messages will help fill the gap in a useful, easily accessible manner."

Recorded at the SBMS studio, the messages feature aid available through the U.S. Federal Emergency Management Agency, the Red Cross, the U.S. Small Business Administration and other local, state and federal agencies; information on insurance coverage and obtaining disability and unemployment insurance; and warnings about scams that tend to surface in the wake of disasters.

Health concerns are addressed in guidelines for donating food to shelters, handling food safely when facing interruptions of power, and dealing with the ever-present blanket of ash, as well as recommendations regarding exposure to smoke and



Robert A. Eplett/OES CA

UC fire recovery resources

<http://ucanr.org/fire/recovery.shtml> (English)
http://espanol.ucanr.org/Temas_Especiales/ (Spanish)
AsisTel de la UC (phone messages): (800) 514-4494

how to know if one's symptoms are smoke-related. Additional messages address handling ash and debris from burned structures and preparing for mudslides.

By Jan. 5, AsisTel de la UC had registered 478 calls. "We will continue updating the messages we provide through AsisTel de la UC on a regular basis, and will add new categories under the general natural disasters heading, such as floods and earthquakes," Grajales-Hall says.

Cedar Fire hits UC wildland reserve

The Cedar Fire, which started on Oct. 25, raged through more than 280,000 acres in south San Diego County, killing 13 residents and one firefighter, and destroying more than 2,200 homes. It also burned most of Elliott Chaparral Reserve, a 183-acre wildlands site near Scripps Ranch that is part of the UC Natural Reserve System.

The site's rolling topography supports a diverse mixture of natural habitats, with an unusually wide variety of southern coastal chaparral. The Cedar Fire burned approximately 95% of Elliott's habitat.

"There are tiny patches that did not burn, in which birds are sheltering – quail, towhee, gnat-catchers, rufous-crowned sparrows," says Isabelle Kay, reserve manager and academic coordinator.

Established in 1969, the reserve serves a small but dedicated group of long-term users. For example, Dan Udovich and others from University of Oregon have been researching the effects of floral predation on the pollination biology and reproductive success of the plant *Yucca whipplei*. Andrew Suarez of UC Davis and Ted Case of UC San Diego investigated the regional decline of native ants and their obligate predator, the coast horned lizard, due to an invasion of non-native Argentine ants.

Current research includes an investigation by David Holway and Sean Menke of UC San Diego into the effects of urban irrigation on the ability of Argentine ants to invade native ecosystems, and a survey of the distribution of the roadrunner by Mark Mendleson at San Diego State University. Both of these studies will continue, taking into account the burned conditions. The direction of work by Udovich will for the moment change in order to take advantage of the burst of recruitment by *Yucca whipplei* in response to the fire.

Fire is a natural part of the chaparral ecosystem and field scientists expect such wildlands to burn



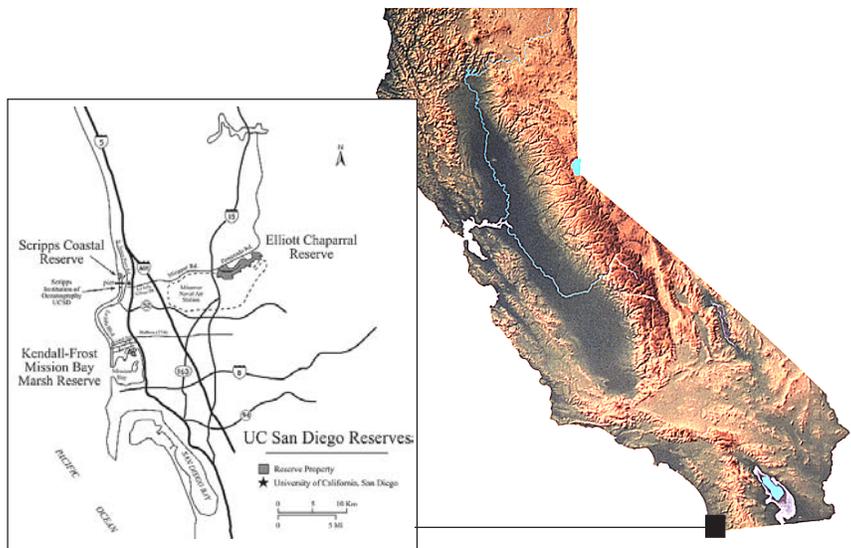
UC's Elliott Chaparral Reserve burned in the Cedar Fire, although houses nearby were spared.

periodically. Furthermore, researchers now have the opportunity to study the role fire plays in stimulating the seedbank, recycling nutrients, altering vegetation and wildlife conditions, and reducing and creating future fire hazards. Kay is supervising a study by Bernice Ramirez, a high school student at the Preuss School on the UC San Diego campus into the effect of slope aspect, burn intensity and the presence of nonnative eucalyptus on the regeneration of the native vegetation.

There were no on-site buildings or other structures at Elliott Reserve, and only one house on adjacent land burned. Reserve personnel are now turning their attention to major safety concerns, such as unstable eucalyptus trees, gaps in the perimeter fencing previously filled by impenetrable chaparral and ordnance dating from World War II, which is now visible on the surface. Erosion on steep slopes is being monitored, but is expected to consist of ash rather than soil. This should not be a major problem since gentle winter rains have resulted in widespread germination of native seedlings and the deep roots of shrubs remain in place.

UC's Natural Reserve System manages 34 wildland sites in California, with 130,000 acres of relatively undisturbed samples of the state's natural habitats.

— Editors



“Pre-caucusing” improves labor mediation

The manager of the agricultural firm was highly valued by his company. But quite often, he lost patience with one of his employees, getting extremely angry, yelling and swearing. The workplace had become an intolerable place for both employees.

When the two men were referred for mediation to Gregorio Billikopf Encina, he was not at all confident that “we could bring these two people together.”

But Billikopf, a UC labor management farm advisor since 1981, employed a deceptively simple technique that he developed and honed over the years as a mediator and an equal employment opportunity counselor for UC. Before the two men were scheduled for a joint session, he met with each of them separately, several times, for numerous hours. He listened to their concerns and allowed each to fully express his feelings, then coached them — via role-playing and other techniques — to present their issues in a nonconfrontational way and to negotiate constructively.

The resulting joint session surprised and stunned even Billikopf. The two men were exceedingly polite and friendly toward each other, chatting so amiably and quickly that Billikopf had trouble keeping up with their agreements. “During the pre-caucus the angry manager gave a lame apology about his anger and swearing,” Billikopf says. “But his apology in the joint session was sincere and effective.”

“Pre-caucusing,” when each party meets separately with the mediator before the joint session, is a critical component of Billikopf’s mediation model. (“Caucusing” refers to side meetings between one of the parties and the mediator.) “This is probably the most important contribution I have made during my 20 years in extension,” says Billikopf, who is based in Modesto and serves San Joaquin, Stanislaus and Merced counties.

Traditional mediation is “directive,” meaning that the mediator’s role is to guide both sides toward a solution. By contrast, in arbitration the third party suggests or enforces solutions. Mediators bring the stakeholders together and ask each

to present his or her case while the other listens. However, Billikopf says traditional mediation sessions often deteriorate, with each side interrupting the other and getting progressively more angry. Furthermore, the mediator may often become heavy-handed and take on the role of an arbitrator.



Some mediators feel that loss of control is unavoidable, part of the process, or even necessary. Most third-party neutrals, however, would probably welcome an approach where such dysfunctional escalations were either greatly reduced or completely eliminated.

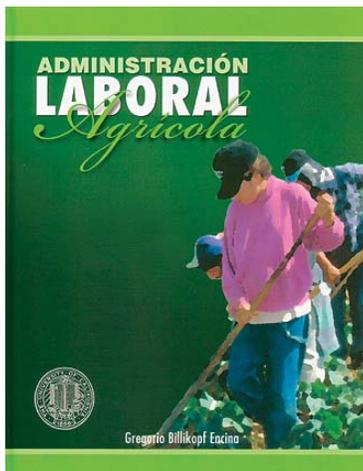
Pre-caucusing reinforces an alternative mode of mediation called “transformative,” first described in the mid-1990s, in which the mediator’s role recedes. Billikopf says he has taken the nondirective approach further, with the parties facing and talking to each other directly during the joint session.

“Because stakeholders address each other rather than the mediator, there is little chance for the mediator to abuse his or her power,” he says. “And as a result of the pre-caucusing, the stakeholders are better prepared to face their contender and negotiate a solution on their own rather than having one suggested or imposed by the mediator.”

Often, the most important function of the pre-caucus is figuring out ways for each side to express pent-up feelings. “It takes courage for people who have been fighting for years to tell the other person how hurt they are,” Billikopf says.

The main concerns expressed by critics of pre-caucusing are that stakeholders may attempt to influence the mediator to take his or her side during the pre-caucus, and that the mediator may become biased.

Pre-caucusing reinforces an alternative mode of mediation called “transformative,” in which the mediator’s role recedes.



Billikopf responds to these concerns in an article on pre-caucusing published in the journal *Group Facilitation* (Spring 2002). He also incorporated information on pre-caucusing into the second edition of his book, *Labor Management in Agriculture: Cultivating Personnel Productivity*, published by the UC Agricultural Issues Center in English and Spanish in mid-2003.

Pre-caucusing is slowly being adopted not only in agriculture and the workplace, but also in other settings where mediators solve interpersonal conflicts such as women's shelters, churches and community mediation centers, as well as by attorneys and professors of conflict management and organi-

zational behavior.

"It also helps facilitators understand factors that affect the likelihood of success," Billikopf says, "so a more informed decision can be made as to whether to bring both parties into a joint session."

Billikopf says his experiences in recent years with pre-caucusing have caused him to reevaluate his initial forays into mediating labor disputes, where he had not sufficiently understood the potential of the pre-caucus. "I wish I knew then, what I know now."

For more information, go to: www.cnr.berkeley.edu/ucce50/ag-labor/.
— Janet Byron

Rural youth report more frequent smoking and drinking

Rural youth report high-risk behaviors such as smoking and drinking alcohol more frequently than their urban counterparts, according to a January report from the UC 4-H Center for Youth Development at UC Davis.

The report, "California's Rural Youth," found that California rural adolescents aged 12 to 17 are nearly four times as likely to smoke cigarettes frequently, and are significantly more likely to drink alcohol.

"The higher rates of smoking among rural youth are of great concern," says lead author Katherine Heck, UC Davis associate specialist.

"In the future, many of these young people will face health problems because of smoking. We found that about 8% of rural adolescents smoked cigarettes regularly, and more than half of them began smoking before age 13." (See page 28 for research on how California's Proposition 10 "tobacco tax" funds are distributed.)

Heck and her colleagues also found that significantly more rural youths (39%) than urban youths (29%) have drunk alcohol. More than one in four (26%) rural California adolescents has ridden with a driver who had been drinking alcohol, compared with 17% of urban youth.

"Rural areas often lack public forms of transportation that might be available in urban areas, so drinking and driving may be a greater problem for rural youth," Heck says.

The UC researchers also found that about 14%

of California's rural youth had no health insurance in 2001, compared with 11% of adolescents statewide. Those rural youth who did have insurance were more likely to be insured through public programs such as Medi-Cal or Healthy Families. Fewer than half of rural adolescents had employer-sponsored health insurance.

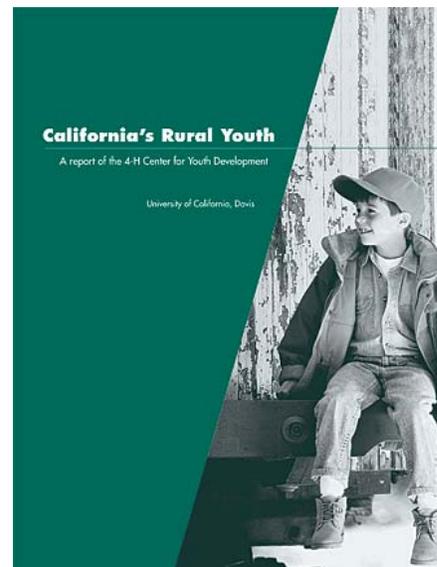
Despite certain challenges, however, rural adolescents have bright futures, says Stephen Russell, director of the UC 4-H Center for Youth Development. "Most rural youth, 79%, said there was a purpose to their lives, and 82% reported having goals and plans for the future."

Russell notes that 65% of rural youth reported they have an adult at home who talks with them about their problems, and 77% have an adult at home who listens when they have something to say.

The report was compiled by a team of researchers and UCCE youth development professionals and draws from multiple sources of state and local data, including the California Health Interview Survey, the California Healthy Kids Survey and the National Longitudinal Study of Adolescent Health.

For more info., go to: <http://fourhcyd.ucdavis.edu>.

— Editors



Eatfit guides adolescents to improve health and fitness

A hip new program called “EatFit” is helping adolescents to change their eating and exercising habits using “guided goal-setting,” a new tool developed by UC nutrition specialists and advisors.

EatFit includes a teen-oriented magazine, interactive Web site and school curriculum designed for 11- to 15-year-olds. The message is one of dietary moderation and common-sense fitness, a critical component of addressing the growing prevalence of obesity among youth and adults (see page 12). Instead of setting their own goals, which is usually unrealistic for middle-school-age children, the program guides them toward achievable lifestyle and habit changes.

About 120 middle schools are using the curriculum, as well as after-school programs and camps, with an estimated 15,000 children participating in 2003.

One evaluation of the program, to be published in the *Journal of Nutrition Education and Behavior* (January-February 2004), found that 74% and 79% of 8th graders participating in EatFit made at least one positive change in their dietary and physical activity behaviors, respectively.

About 120 middle schools are using the curriculum.

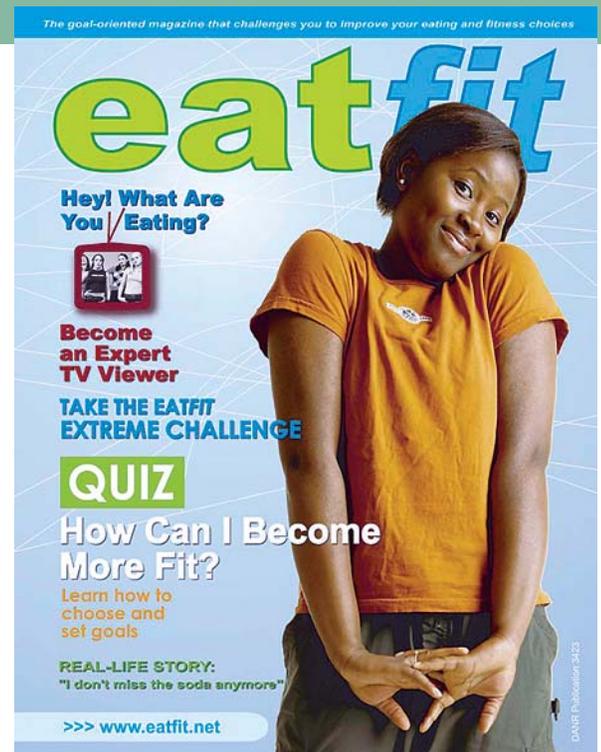
To develop the materials, UC researchers conducted interviews with children and their teachers.

“We found out that we needed to be hip,” says Marilyn Townsend, UC Davis nutrition specialist and leader of the EatFit group. “That’s why we went with the magazine format for kids. They also told us that they wanted a computer component.”

The 20-page magazine and workbook incorporates elements you might find in *Seventeen* or *Teen People*: “fab features,” quizzes, lively colors, skateboards, food and irreverent facial expressions.

The Web site, www.eatfit.net, includes recipes and success stories that provide fun ways to gather information and get motivated, plus an innovative online analysis to help teens evaluate how they currently eat and determine healthy goals. Users type in the foods they ate in a 24-hour period. The site helps narrow down specifics on types of food and serving sizes, then gives a brief analysis and offers two goals for making the diet healthier. The teen selects one, and then is given a selection of small habit changes to help achieve that goal.

“We know that eating too much refined sugar is



an issue with kids, and that girls aren’t getting enough calcium,” says Marcel Horowitz, a researcher on the project. “We present those as goal options. They may not choose them, but once they learn the process and experience success, they might be willing to look at another area in their diets that would be beneficial to change.”

The researchers used goal options in the Web site that students themselves suggested. “We asked kids, ‘If you were going to increase calcium, how would you go about it?’” Townsend says. As a result, users may choose to drink the milk leftover in their cereal bowls three times per week as one goal option.

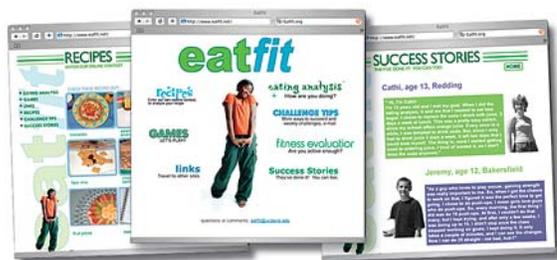
“Instead of saying ‘drink more milk,’ we made each minor goal specific, challenging and something they can do right away,” Townsend says. “If we let the kids set their own goals, they tended to be too general, too easy or too difficult.”

Developed by Horowitz and recent UC Davis Ph.D. graduate Mical Shilts, the EatFit magazine provides analyses for four areas of physical activity: aerobic, stretching, strength and lifestyle. Each has major and minor goal options for students to select, depending on their interests.

“The lifestyle area is where we hope to have the greatest impact on obesity,” Horowitz says. “We offer options for things people can do consistently that don’t require the motivation necessary to participate in organized fitness sessions.”

The idea is to make physical activity a part of everyday life.

“We teach them they don’t need to find a parking place close to the door,” Horowitz says. “Instead of riding the elevator, they can take the stairs.”



The EatFit Web site targets early teens.

Just sitting in the garden pulling weeds uses more calories than watching television.”

The nine-lesson classroom curriculum includes topics such as reading food labels, eating at fast-food restaurants and understanding the media’s influence. Students track their eating and fitness progress, and receive motivating incentives such as raffle tickets and prizes. The lessons are correlated to California Department of Education standards.

Teachers can obtain the curriculum at <http://anrcatalog.ucdavis.edu> or UC Cooperative Extension offices, and receive training and support from UC nutrition advisors. For information, call (530) 754 8051 or go to <http://groups.ucanr.org/efnepyouth/index.cfm>.

— Jeannette Warnert and Janet Byron

Sustainable ag lectures online

A major lecture series at UC Davis, “The Science of Sustainable Agriculture: Measuring the Immeasurable,” which included 17 internationally recognized experts on sustainability in relation to agriculture, the environment and society, is available online.

Sustainable agriculture has stimulated public debate about where food comes from and the interplay of food production, food security (see pages 12, 18) and the protection of human and natural resources. “University research and education play a key role in assessing and increasing the sustainability of the food and agricultural systems,” said Neal Van Alfen, dean of the UC Davis College of Agriculture and Environmental Studies, a major funder of the series.

The series began last April and continued every Friday afternoon through the fall. Speakers included experts in nutrition, biodiversity, climate change and organic farming from around the nation and world.

For more information, go to: www.sarep.ucdavis.edu/seminar/.

Yo-yo dieting drives up obesity

Dieting is not the answer to the nation’s obesity problem (see page 12), according to Joanne Ikeda, extension nutrition specialist at UC Berkeley. For many extremely overweight people, repeated dieting contributes to their weight gain.

Ikeda surveyed 149 women who weighed between 200 and 600 pounds about their lifetime dieting practices. Contrary to the popular public belief that fat people make little effort to lose weight, she found that 60% of the women had dieted more than 11 times, and this figure increased to 83% for women at the highest weights.

“The first time, they will lose a significant amount of weight, then regain a few pounds more than they lost. The second time it will be more difficult to lose weight. They won’t lose as much as the first time. The weight regain will be faster and greater than the first weight regain,” Ikeda says.

The \$30-billion diet industry encourages overweight people to keep on trying to lose weight and many continue the frustrating yo-yo pattern believing that eventually they will succeed. However, Ikeda said, research shows that few do.

“My concern is that one of the things driving up the obesity rate is weight loss and regain in these individuals,” she says. “I think that once people have tried to lose weight three times and regained the weight each time, they should be encouraged to stop dieting before their weight goes even higher.”

Ikeda says the focus should shift to health at every size. She recommends that overweight women exercise regularly and eat nutrient-dense foods amounting to approximately 1,800 calories per day. Such a plan will satisfy hunger with three reasonable meals plus snacks, in contrast to typical weight-loss diets of 1,200 to 1,400 calories per day.

“The goal is weight maintenance, not weight loss,” Ikeda says. “This strategy will reduce the risk for chronic diseases, such as type 2 diabetes, coronary heart disease and stroke.”

Ikeda found the subjects for her study by collaborating with the Sacramento-based National Association to Advance Fat Acceptance, and sending messages to mailing lists that reach overweight women. Complete results of Ikeda’s research will be published in 2004 in the *Journal of the American Dietetic Association*.

— Jeannette Warnert



Rather than dieting, obese women should focus on exercising and eating healthy, nutrient-dense foods.

How can Californians be overweight and hungry?

Patricia B. Crawford
Marilyn S. Townsend
Diane L. Metz
Dorothy Smith
Gloria Espinosa-Hall
Susan S. Donohue
Anna Olivares
Lucia L. Kaiser

The United States is experiencing an epidemic of obesity in both adults and children, particularly among low-income populations. In fact, overweight has replaced malnutrition as the most prevalent nutritional problem among the poor. We examine this seemingly paradoxical relationship and explore the causes and consequences of overweight, obesity and food insecurity. In a UC Cooperative Extension Body Weight and Health Workgroup study of 561 low-income Latino mothers and their young children, we found important differences in the association between family food insecurity and overweight status for mothers and their children. Forty percent of the women were overweight and 37% obese, and 22% of their children were overweight. Furthermore, U.S.-born mothers who were food insecure as children were more likely to be obese adults. Awareness and understanding of the link between food insecurity and weight gain will facilitate the efforts of schools, food assistance programs, the food industry and others in the community to provide effective nutritional programs.

Obesity has become an epidemic among U.S. adults and children during the past 30 years and threatens to overwhelm our health care system. According to the 1999–00 National Health and Nutrition Examination Survey (Flegal 2002), 64% of U.S. adults (ages 20 to 74) are either overweight or obese. The percentage of overweight children and adolescents has tripled in the last 30 years (Ogden et al. 2002). An overweight child is likely to become an overweight adult, with consequent health risks. Approximately three-quarters of teenagers who are overweight will grow up to be overweight or obese adults (Whitaker et al. 1997).

Although overweight is often considered a problem of overeating rather than hunger and scarcity, low-income adults and children have gained the most weight in recent decades. Rates of obesity and overweight among the poor are increasing, while the number of poor Americans experiencing food insecurity remains high, at an estimated 30 million (Olson and Holben 2002). How can we explain the coexistence of overweight and food insecurity among the poor? To answer this question, UC Cooperative Extension (UCCE) advisors and specialists — members of the Body Weight and



To explore the relationship between overweight and food security, a UC workgroup studied 561 low-income Latino mothers and their children. Forty percent of the women were overweight and 37% obese, and 22% of their children were overweight. UC Cooperative Extension nutrition instructor Mariana Castro measures Samuelito in Richmond.

Health Workgroup — examined a large sample of low-income Latino mothers and their young children.

Weight and health, economic status

Overweight is associated with increased risk of disease, causing considerable concern among health care professionals (see box, page 13). Numerous chronic diseases are associated with childhood as well as adult overweight. Diseases associated with obesity and overweight will soon rival cigarette smoking as the leading cause of preventable premature death and disability in the United States, according to the U.S. Surgeon General's Call to Action (US DHHS 2001).

The prevalence of obesity in the United States has grown rapidly in the last 30 years, during a time of economic prosperity. However, the increasing incidence of obesity does not necessarily reflect a more affluent lifestyle or increased availability of food resources.



Socioeconomic status is one way to gauge family or household food-security status. Indeed, people of low socioeconomic status and those who experience food insecurity, along with certain racial and ethnic groups, are at a disproportionately higher risk for obesity and health-related conditions. In fact, overweight has replaced malnutrition as the most prevalent nutritional problem among the poor.

Evidence suggests that associations between socioeconomic status and overweight differ by gender. The 1997–98 National Health Interview Survey (NHIS) found that men with incomes below the poverty level (57%) were somewhat less likely than men in the highest income group (64%) to be overweight (Schoenborn et al. 2002). However, women below the poverty level (57%) were considerably more likely to be overweight than women earning the highest incomes (38%).

Although children at all levels of society have grown heavier, those at the bottom of the socioeconomic scale have gained the most weight. Recent studies suggest that low socioeconomic status may be a risk factor for overweight among children as young as preschool age (Gerald et al. 1994; Sherman et al. 1995). The prevalence of overweight among 4-year-olds in the Supplemental Feeding Program for Women, Infants, and Children (WIC) was 10.6% (Mei et al. 1998), compared with 7.9% for a nationally representative sample of 4- to 5-year-olds (Ogden et al. 1997). Similarly, several studies of low-income preschool children attending Head Start programs found a high prevalence of overweight, ranging from 10% (Wiecha and Casey 1994) up to 32% (Hernandez et al. 1998).

Lower educational level is also associated with higher weight among both men and women, although the association is more striking for women. About six in 10 adults without a high school diploma were overweight compared to

52% of those with a graduate degree (Schoenborn et al. 2002). Similarly, some studies show an inverse relationship between weight and household income, and weight and parental education in children and adolescents, particularly among white children (Goodman 1999).

Influence of ethnicity

The 1997–98 NHIS (sample of 68,556 adults) found that black and Latino adults were twice as likely as Asian adults to be overweight (Schoenborn et al. 2002). Slightly more than one-half of white adults were overweight in the 1997–98 NHIS. The highest rates for childhood overweight were found in Latino and Native American children and black girls.

How do we distinguish between the influence of socioeconomic status and that of race or ethnicity? White children from lower income families experience a greater prevalence of overweight than those from higher income families (Troiano and Flegal 1998). However, family income does not reliably predict overweight prevalence in Mexican American and black children. An association between socioeconomic status and overweight has been found in white girls, but not in black girls (Patterson et al. 1997).



Women of low socioeconomic status are about 50% more likely to be obese than those at high incomes, while for men the obesity risk is similar regardless of income.

Overweight and obesity are risk factors for:

- Diabetes
- Heart disease
- Stroke
- Hypertension
- Gallbladder disease
- High blood cholesterol
- Complications of pregnancy; infertility
- Menstrual irregularities
- Increased surgical risk
- Osteoarthritis (degeneration of cartilage and bone of joints)
- Sleep apnea and other breathing problems
- Some forms of cancer (uterine, breast, colorectal, kidney and gallbladder)
- Stress incontinence (urine leakage caused by weak pelvic-floor muscles)
- Psychological disorders such as depression

Glossary

Food security: Access by all people at all times to enough food for an active, healthy life. It includes at a minimum: (1) the ready availability of nutritionally adequate and safe food; and (2) an assured ability to acquire acceptable food in socially acceptable ways (such as without resorting to emergency food supplies, scavenging, stealing or other coping strategies).

Overweight and obesity: Regardless of gender, adults with a body mass index (BMI) between 25 and 30 are described as overweight, and with a BMI of 30 or more as obese. BMI is calculated by dividing weight (in kilograms) by height (in meters) squared. Children who are at or above the 95th percentile of BMI, using Centers for Disease Control (CDC) standards, are termed overweight. There is no one BMI cutoff for children because the number changes with age. Children at or above the 85th percentile are categorized as at risk for overweight. The term obesity is generally not used with children.

TABLE 1. Demographic characteristics of study participants (n = 561)

Demographic	Mother	Child	Household
Age (years)	29.3 ± 5.9*	3.8 ± 0.7	
Education (years)	8.8 ± 3.6		
Monthly Income, % (n)			
< \$750			14 (79)
\$751–1,000			19 (105)
\$1,001–1,250			20 (112)
\$1,251–1,500			15 (84)
\$1,501–1,750			10 (54)
\$1,751–2,000			8 (48)
> \$2000			14 (77)
Assistance programs, % participation (n)			
WIC			78 (436)
Head Start			26 (144)
TANF			14 (76)
Food stamps			26 (144)
Household size (persons)			4.3 ± 1.7
Language preferred at home, % (n)			
Spanish			76 (426)
English			11 (62)
Both			13 (73)
Country of birth, % (n)			
Mexico	78 (438)		
United States	19 (107)		
Other (Central America, Peru)	3 (16)		
Time living in U.S. (years)	13 ± 9		
Body measurements			
Height (inches)	61.6 ± 2.3	40.9 ± 2.7	
Weight (lbs)	158.7 ± 34.4	41.0 ± 9.7	
BMI, wt/ht ²	29.4 ± 6.1	17.1 ± 2.8	

* Values are means ± standard deviation.

Nutrition and food insecurity

Overweight is generally associated with excessive food intake while food insecurity is associated with inadequate food supplies. How can both be found in the same individuals and households? Overweight is not just a function of the quantity of food consumed and can mask other nutritional problems that result when families have insufficient money for food. One possible scenario is that high-fat, high-sugar foods are the cheapest source of calories for low-income parents to buy. Reliance on these foods may contribute to weight gain, especially when it occurs cyclically in response to dwindling food dollars. Another scenario is that low-income parents may buy less high-fat, high-sugar foods when they are food insecure and then indulge in more when they have money.

While these scenarios focus on individual behavior, another considers the genetics of obesity. In examining the relationship between food insecurity and overweight among the poor, recent studies have begun to look at the possi-

hypothesis of obesity suggests that those exposed to fluctuating calorie intakes develop adaptive methods to achieve high efficiency in energy use and deposition of fat stores (Neel 1962). The thrifty gene, which favors energy storage, may have been adaptive for early humans or traditional societies faced with periodic famine but is no longer beneficial in modern societies.

Yet another theory focuses on some evidence that low socioeconomic status leads to psychosocial stress, promoting increased fat deposition in the abdomi-



Suzanne Paisley

Overweight is not merely a function of the amount of food consumed; rather, it can indicate the challenging nutritional decisions that families must make when money is short. *Left*, UC Cooperative Extension offers nutrition education and food preparation classes.

bility that the body may make permanent changes in response to periodic food shortages, leading to increased body fat when food becomes available. For example, the thrifty genotype

nal area through psychoneuroendocrinological pathways (Bjorntorp 1995). In spite of the many plausible theories, we still do not know all of the factors contributing to the obesity epidemic.

Studies have found a relationship between overweight/obesity and food insecurity in adult women. Using a nationally representative sample of the U.S. population, women who were mildly and moderately food insecure (defined as having enough to eat but not always the preferred kinds of food) were more likely to be overweight than those who were food secure (Townsend et al. 2001). Controlling for other variables, these women were 30% more likely to be overweight in this study. Similarly, other studies with small sample sizes have found that the relationship between food insecurity and obesity found in women is not observed in men and young children. While it is not clear why this is so, it could potentially have something to do with the woman's role as caregiver, where she tries to protect

TABLE 2. Association between household food insecurity, maternal obesity and child overweight (n = 561)

Household food security†	Sample	Mother	Child	
		Obese (BMI ≥ 30)	At risk for overweight (BMI ≥ 85th*)	Overweight (BMI ≥ 95th*)
Fully food secure	27	33.3	36.6	20.3
Marginally food secure	22	35.2	39.2	23.2
Food insecure without hunger	39	37.2	34.3	20.8
Food insecure with hunger	12	50.8	47.8	28.4
Significance		P < 0.05	ns‡	ns

* Percentile.

† As assessed by U.S. Food Security Survey Module (<http://ers.usda.gov/briefing/FoodSecurity>).

‡ Not significant.



In the UC study, obesity in U.S.-born Latino women was related to childhood experiences of food insecurity. Above, schools play an important role in teaching healthy eating habits.

the health of other family members through differential allocation of the scarce food resources.

Study of Latino mothers, children

The UCCE Body Weight and Health Workgroup convened seven advisors, four specialists and four other professionals to study the relationship between food insecurity and overweight in both women and children. A large group ($n = 561$) of low-income, mainly recent immigrant Latino mothers and their children aged 3 to 6 years, was selected for study. The families were recruited from four rural (San Benito, San Joaquin, Stanislaus, Tulare) and two urban (Contra Costa, Sacramento) California counties with high percentages of low-income Latino families. We hoped to answer four questions:

- Is current household food insecurity related to overweight among the mothers?
- Is a woman's childhood food insecurity related to her overweight as an adult?
- Is current household food insecurity related to overweight status of her child?
- Is a mother's past food insecurity related to her child's current weight status?

In 2001, our bilingual interviewers recruited mothers with the help of community-based agencies that serve food-insecure families, such as the WIC program, Head Start, migrant camps, health departments, health centers and family resource centers. To be eligible

for participation, a mother needed to: (1) identify herself and her child as Mexican, Latino, Hispanic or similar; (2) have given birth to at least one child between June 1, 1995, and Feb. 1, 1998; (3) have a family income at or below 200% of the poverty level; (4) be at least 18 years old or an emancipated minor; and (5) sign a consent form. Mothers who were pregnant, planned to move in the next 2 weeks or had reported or perceived issues or illnesses that could influence accurate responses were excluded. We interviewed participants in private rooms in the health or WIC clinics, and in their homes if necessary. At the end of the interview, each participant received a gift certificate worth \$20 at a local store.

We carefully measured the heights and weights of all mothers and children, and asked questions related to age, mother's education, household income, participation in food and monetary assistance programs, household size, language spoken at home, country of birth and years in the United States (table 1). Additionally, we used the 18-item U.S. Food Security Survey Module, formerly known as the Core Food Security Module, to collect data pertaining specifically to our four study questions and assess household food insecurity. Because that instrument only asks about food insecurity during the last 3 months, we added questions about food security during the past 12 months and during the mother's childhood. A food insecurity score was calculated based on the responses to these questions.

Widespread overweight and obesity

Of the low-income mothers in our study, 40% were overweight and 37% were obese. These numbers are similar to recent national figures for Mexican American women of all ages classifying 32% as overweight and 40% as obese (Flegal et al. 2002). Twenty-two percent of the children we studied were overweight, double the recent national prevalence of 11% for Mexican American 2- to 5-year-old children (Ogden et al. 2002).

We found that many of the women experiencing food insecurity were overweight (table 2). Approximately 60% of the women reported that their food situation was currently insecure. In our group of Latino mothers of young children, current food insecurity was directly related to overweight. As food insecurity increased, the likelihood that a mother was overweight also increased. We did not find a comparable relationship between current household food insecurity and overweight among the children.

Among some women, overweight was also related to the childhood experience of food insecurity. Seventy-eight percent of the women reported past experience of food insecurity in their own childhood. Interestingly, mothers who experienced severe levels of food insecurity as children were somewhat more likely to now be raising children who were overweight compared to other children in our study. In other words, the experience of food insecurity may influence the next generation to come.

Economics influences food habits

Why is food insecurity of these mothers related to overweight? There are monthly, seasonal and cyclical changes associated with variable incomes, changing food allowances and food availability, and other changing family and household circumstances. This variability may lead to eating patterns conducive to unhealthy weight gain. For example, during periods when funds are available for food purchases, there may be episodic binge-



Role of food assistance programs

Some preliminary data indicates that participation in food assistance programs may improve food choices and reduce the prevalence of overweight. Nutrition education provided by the Expanded Food and Nutrition Education Program (EFNEP) and the Food Stamp Nutrition Education Program (FSNEP) teaches clients how to change their diets by shopping, preparing and serving more healthful foods to their families. In addition, a steady supply of food dollars (such as food stamps or WIC vouchers) can also allow families to make healthier choices (Mitchem 2003).

A study by the Centers for Disease Control and Prevention (1996) concluded that the WIC program for low-income children provides foods with essential nutrients without contributing to overweight.



Exposure to lifelong activities such as swimming, at this public pool in Parlier, above, as well as dancing, aerobics and running, can help children develop healthy exercise habits.

eating to compensate for times of deprivation. When food and money is available families may snack more and eat at fast-food restaurants. And during insecure periods, meal patterns may be altered and lower-priced, readily available foods with higher fat content may be consumed.

A crucial finding of our study was that obesity prevention requires that food selection, even in food insecure families, should be directed toward healthful choices. We also found that childhood circumstances may have a large impact on adult life and dietary preferences are often molded at a young age. Although household food insecurity was not related to overweight among the young children we studied (table 2), we do not know whether that relationship changes as the children mature. While longitudinal data must be collected to confirm our findings, we suspect that the effects of food insecurity may be carried across generations.

Healthy lifestyle choices

UCCE plays an integral role in addressing major health issues at the community level. This study laid the foundation for workshops targeting health professionals and policymakers in the six counties studied and for the development of education interventions targeting food-insecure, low-income Latino families.

Obesity is an extremely complex health issue influenced by many factors; successful interventions must include multiple approaches and partnerships. The Body Weight and

Health Workgroup believes that a comprehensive approach must include policy changes in the food assistance programs, schools, food industry and the greater community. Implementation of these recommendations can empower community members to make healthy lifestyle choices.

Food assistance programs. In their capacity as direct service providers, food assistance programs can assist food banks and emergency food pantries to provide healthful food supplies; ensure that using food stamps is easy for shoppers, vendors and farmers; fund and promote programs linking low-income groups to healthy foods such as the WIC Farmers Market Nutrition Program; enhance food-stamp outreach to include the elderly and working poor; and ensure that nutrition education is available to all food-insecure families.

Food industry. The food industry should be encouraged to limit marketing targeting children; provide healthy food and beverage selections in school vending machines; and label fast foods to show fat, sugar, sodium and calories.

Schools. After family, schools provide the best opportunity for teaching healthy eating habits. They can teach basic food-preparation skills and the benefits of healthy eating and physical activity; provide longer physical education classes that promote lifelong activities such as dance, step aerobics, weight training and swimming; promote peer support groups or clubs where students can learn and practice skills in healthy eating and



The workgroup recommends a comprehensive approach to addressing the epidemic of overweight, via partnerships with food assistance programs, schools, the food industry and community programs. For example, *left to right*, community programs such as gardens can help families get exercise while growing healthy food, and schools can show kids fun ways to be active and prepare healthy snacks.

physical activity; sponsor physically active family events; and create an emotionally safe environment where everyone is encouraged to participate in physical education activities regardless of size and ability.

Community groups. Community groups can advocate for safe, clean neighborhood areas conducive to physical activity and recreation, including sidewalks, crosswalks, bicycle and walking paths, parks and open spaces; physical education and nutrition in schools; and smaller portions and more healthful foods in restaurants.

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thank Katherine Flegal, Nancie Hughes and Leah Rimkus for their contributions to the preparation of this paper.

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Food insecurity prominent among low-income California Latinos

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Food security is defined as access by all people at all times to enough food for an active, healthy life. In a study of 212 low-income Latino households in California, 45% were food insecure without hunger; 13% food insecure with moderate hunger; and 3% food insecure with severe hunger. Food insecurity was associated with a decline in household supplies of both nutritious and less nutritious foods. Among preschool children, the number of servings per day of all food groups was significantly correlated with household food supplies. A strong safety net to improve food security in low-income populations must include educational strategies and provision of nutritious foods to support a good diet at home and away from home.

People sometimes wonder whether hunger really exists in the United States, a land of plenty. Clearly, the phenomenon is different here than in many developing countries. “Food insecurity” is a relatively new concept that emerged in the early 1980s. Much of the research in the past 15 to 20 years has focused on developing a conceptual framework and instruments to measure the extent of the problem in this country. Little is known about the nutri-



Yolo County Children & Families Comm.

Food security is a relatively new concept for describing a person’s access to enough food for an active, healthy life. In a study of low-income Latino families, preschool-age children had less to eat when household food stores were low. Above, a Yolo County girl learns to make tortillas.

tional and health implications of the milder forms of food insecurity that are more common in the United States than severe hunger.

Food security is defined as the access by all people at all times to enough food for an active, healthy life (Anderson 1990). At a minimum, food security includes: (1) the availability of nutritionally adequate and safe foods, and (2) the ability to acquire acceptable food in socially acceptable ways. Whenever the food supply or ability to acquire food becomes limited or uncertain, households are considered “food insecure” (Hamilton et al. 1997). “Hunger” refers specifically to the uneasy or painful sensation caused by lack of food. At a mild level of food insecurity without hunger, household members become anxious about their food supplies and begin to make adjustments in the type and amount of food purchased. When household members skip meals or otherwise cut back on the amount of food they consume, food insecurity with hunger occurs. At a moderate level of hunger, adult household members experience hunger. The most severe level of hun-

ger is felt when the household’s children are hungry.

Since 1995, the federal government has collected data annually on the prevalence of food insecurity and hunger in the United States using an 18-item Food Security Supplement (FSS) as part of the Current Population Survey (see box, page 19). This instrument is designed to detect different levels of food insecurity by the number of affirmative responses to the 18 items. Households are classified according to the number of affirmative responses: food secure (0 to 2); food insecure without hunger (3 to 7); food insecure with moderate hunger (8 to 12); and food insecure with severe hunger (13 to 18).

Although poverty and food insecurity are correlated, not all low-income households report being food insecure, partly due to the availability of food assistance programs and their informal support systems (Rose 1999). Similarly, sudden changes in employment status or the addition of a new member to the household may cause some households with higher income levels to be food insecure. Therefore, asking people directly about the adequacy of their



Latino households nationwide report higher levels of food insecurity than other ethnic groups. Focus groups in California found that seasonal food insecurity among low-income Latinos is related to fluctuations in jobs such as agriculture and construction labor. Above, families share snacks and meals.

household food supplies is important in monitoring the extent to which basic needs are met.

Trends in food security and hunger

Data from the Current Population Survey indicates that the prevalence of food insecurity in California from 1996 to 1998 was higher than the national average (11.4% versus 9.7%) (Nord et al. 1999). As might be expected, the prevalence of food insecurity and hunger in California and the nation fluctuates in response to economic conditions. Between 1995 and 2000, food insecurity declined for most households and all regions of the United States, probably due to the improved economy (Andrews and Nord 2001). However, households with incomes less than 130% of the poverty level actually reported higher levels of food insecurity during the same time. Meanwhile, the use of emergency food pantries and kitchens also appeared to increase between 1996 and 2000 (Nord et al. 2003).

In 2001, the U.S. Department of Agriculture (USDA) Economic Research Service predicted that food insecurity would increase nationwide, reflecting the economic recession that began in 2001. In fact, their predictions were correct: the most recent USDA data reports that 11.1% of U.S. households were food insecure in 2002, up from 10.5% in 2000 (Nord et al. 2003).

Developed by federal agencies with input from more than 250 state health agencies and 350 national organizations, the Healthy People 2010 (2000) report included numerous national health and nutrition objectives, including the reduction of food insecurity by half. To achieve this objective by 2010, it will be necessary to improve employment and income opportunities for less-skilled workers and single mothers

with young children, and to maintain a strong nutrition safety net.

Nutrition and health implications

Across diverse ethnic groups, food insecurity is associated with lower household supplies and consumption of fruit and vegetables (Kendall et al. 1996; Derrickson et al. 2001; Matheson et al. 2002). Intake of vitamin A, folate, iron, magnesium and zinc is particularly low among women in moderately to severely food-insecure households (Tarasuk and Beaton 1999). Intermittent episodes of food restriction due to financial constraints may actually lead to overeating at a later time when families have more money to spend. Research has found an association between food insecurity and overweight in women (Townsend et al. 2001; Olson 1999). Food insecurity has also been linked to emotional, psychological and academic problems in school-age children (Kleinman et al. 1998).

Food insecurity among Latinos

Latino households comprise a diverse and rapidly growing segment of the U.S. population and report relatively high levels of food insecurity compared to other ethnic groups (Alaimo et al. 1998; Nord et al. 2003). Focus group discussions in California revealed that many low-income Latino households experience seasonal cycles of food insecurity related to lack of agricultural and other employment such as construction during the winter (Melgar-Quinonez et al. 2003).

These households may be able to purchase traditional staples in bulk during the summer to use later but cannot afford certain perishable or other desired items during the winter. When households are anxious about their food supplies, homemakers often at-

Selected questions from 18-item Food Security Supplement of the Current Population Survey

Household-level food insecurity:

- “We worried whether our food would run out before we got money to buy more.” (Was that often, sometimes or never true for you in the last 12 months?)
- “The food that we bought just didn’t last and we didn’t have money to get more.” (Was that often, sometimes or never true for you in the last 12 months?)

Adult-level food insecurity (moderate hunger):

- In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn’t enough money for food? (Yes, No, Don’t know / Refused)
- In the last 12 months were you ever hungry but didn’t eat, because you couldn’t afford enough food? (Yes, No, Don’t know / Refused)

Child-level food insecurity (severe hunger):

- (For households with children) In the last 12 months, did your child / any of the children ever skip meals because there wasn’t enough money for food? (Yes, No, Don’t know / Refused)
- (For households with children) In the last 12 months, did your child / any of the children ever not eat for a whole day because there wasn’t enough money for food? (Yes, No, Don’t know / Refused)

Note: The complete 18-item instrument and instructions for its use are at the USDA Food and Nutrition Service Web site: www.fns.usda.gov/fsec/FILES/FSGuide.pdf.

TABLE 1. Characteristics of participant families (n = 212)*

Mother's age (yrs.)†	29.2 (± 5.5)
Child's age (yrs.)†	3.8 (± 0.7)
Child's gender‡:	
Girls	51% (108)
Boys	49% (104)
Mother's length of residence in United States (yrs.)†	12.7 (± 8.8)
Mothers born in Mexico or other Latin American country (yes)‡	83.5% (177)
Per capita household income (\$/person/mo.)†	268 (± 131)
Household size (no.)†	5.2 (± 1.7)
Currently on WIC (yes)‡	78% (166)
Currently on food stamps (yes)‡	25% (55)

* Data was collected on families (income, food security, household size); however, only mothers and preschoolers were measured (weight and height).

† Mean (standard deviation).

‡ % (n).



Suzanne Paisley

The household inventory included foods used in traditional Mexican meals, above, such as tortillas, rice and beans, and avocados.

tempt to stretch a main dish and allocate a little less to all family members. In some situations, the mother may cut back on her own food intake first, attempting to spare both the adult male wage earner and the youngest children.

In a California study conducted among 238 Mexican American households during winter 1998, food insecurity was significantly associated with higher intakes among preschoolers of beans and tortillas and lower intakes of low-fat milk, cooked vegetables, pizza, cookies, crackers and other desserts (Kaiser et al. 2002). Overall, the diets of preschoolers in severely food-insecure households were less likely to meet the USDA Food Guide Pyramid recommendations, compared to more food-secure households. These findings demonstrate that cyclical patterns of food insecurity are associated with a less varied diet. More studies are needed to determine whether permissive attitudes about snacking and food selection, following periods of anxiety and food restriction due to seasonal food insecurity, might

contribute to greater consumption of high-fat and/or high-sugar foods among Latino children.

UC Cooperative Extension research

The UC Cooperative Extension (UCCE) Body Weight and Health Workgroup recently conducted a study related to food insecurity and overweight among 561 Latino families (see page 12). The study was a cross-sectional survey of low-income households (administered at one time to all subjects), carried out between February and May 2001, in six California counties. They included rural counties on the coast or in the Central Valley (Tulare, San Benito, San Joaquin, Stanislaus) and urban counties (Contra Costa, Sacramento). This paper focused on a subset of 212 families, randomly selected to provide additional dietary data. The objectives were to examine the impact of food insecurity on household food supplies and preschooler food patterns, and discuss the implications for strengthening the nutrition safety net.

The survey included the 18-item U.S. Household Food Security Scale (FSS) (Bickel et al. 2000); a 171-item self-reported household food inventory (Beto et al. 1997); and a 66-item food frequency questionnaire (Kaiser et al. 2002). To improve the clarity of the research instruments we conducted focus group testing; pilot-testing among 20 low-income Latino families recruited through the Special Supplemental Nutrition Program for Women, Infants, and Children

(WIC); and cross-checking of the final translated instrument by eight native Spanish speakers from Mexico, Central America and South America.

To be eligible for this study, participants had to meet the following criteria: (1) mother identified herself and her child as Latino, Mexican or Hispanic; (2) mother had at least one biological child born between June 1, 1995, and Feb. 1, 1998; (3) family had income at or below 200% of poverty level; (4) mother was 18 years or older (or an emancipated minor); and (5) subject was willing to sign the Human Subjects consent form approved by the UC Davis Institutional Review Board. People were excluded for any of the following: mother was currently pregnant or pregnant within the last 3 months; mother planned to move within the next 2 weeks; interviewer perceived or mother reported alcohol or substance abuse, mental illness or other illness that could affect accurate responses, body weight or diet. If the family had more than one eligible child between 3 and 6 years old, interviewers randomly selected the target child by coin toss.

For the study of 561 families, interviewers recruited a convenience sample from community-based agencies including WIC, Head Start, migrant camps, the local public health department, local health centers and family resource centers. Some interviews were conducted in the subjects' homes, but most took place in private rooms in health or WIC clinics. Interviews were conducted in English or Spanish, depending on the subject's preference. Interview length was 45 to 60 minutes. At the end, the subject received a gift

Suzanne Paisley



When household food supplies are low, mothers may cut back on their own intake so that young children are not hungry.

TABLE 2. Percent of low-income, food-secure Latino households that report having food items in their homes
(*items in italics reported significantly less often as food insecurity increased*)

Grains	Fruit	Vegetables	Dairy	Protein foods	Other
75% or more of households					
<i>White rice</i> <i>Noodles</i> <i>Pancake mix</i> Corn tortillas White bread WIC cereal	<i>Apples</i> <i>Bananas</i> <i>Oranges</i> <i>Lemon/lime</i> <i>Fruit juice</i>	<i>Carrots</i> <i>Lettuce</i> <i>Potatoes</i> <i>Tomatoes</i> <i>Corn</i> Onion/garlic Chile peppers	<i>Cheese</i> Whole milk	<i>Beef</i> <i>Peanut butter</i> Chicken, whole Beans (pinto, black) Eggs	Oil Mayonnaise Broth
50% to 74% of households*					
<i>Whole-wheat bread</i> <i>Flour</i> <i>Crackers</i> Oatmeal Instant noodle soup Corn masa/bread Flour tortillas Packaged pasta mix		<i>Cucumber</i> <i>Bell peppers</i> <i>Avocado</i> Green peas/beans Cabbage Broccoli	<i>Yogurt</i> <i>Sour cream</i> Ice cream	<i>Ham</i> Chicken breast Tuna	<i>Soda</i> <i>Cookies</i> <i>Powdered chocolate</i> <i>Gelatin</i> <i>Margarine</i> <i>Tea</i> <i>Salad dressing</i> Butter Coffee
25% to 49% of households					
<i>Pan dulce</i> <i>Popcorn</i> Non-WIC cereals (sweetened) Cake mix Atole	<i>Peaches</i> <i>Grapes</i> <i>Jicama</i> <i>Melon</i> <i>Mangoes</i> Pears Dried fruit Berries	<i>Mixed vegetables</i> <i>Squash</i> <i>Cactus leaves</i> Celery Radish Chayote	<i>Low-fat milk</i>	<i>Nuts</i> <i>Fish</i> <i>Bacon</i> Beef/turkey franks Shellfish/shrimp Garbanzos/lentils Pork Sausage/salami	<i>Pickles</i> <i>Creamer</i> <i>Chips</i> Kool-Aid Fruit punch Popsicles Candy

* In these households, none of the fruits on the inventory were reported.

certificate worth \$20 at a local store.

We used the Food Guide Pyramid recommendations to calculate the number of servings per week from each food group (USDA 1999). In addition to the five main food groups, another category included daily servings of snack foods (cookies, crackers, candy, popsicles, ice cream, hot dogs, cheese). These foods were selected based on findings from focus group discussions about preschooler snacking behavior in a previous study among Latino parents (Kaiser et al. 1999). To examine the relationship of food insecurity and household food supplies, we created scales for several food groupings, including grains, dairy, meats, vegetables, fruits and snack foods. Each food item was assigned a score: "1" if present in the household at the time of the interview or "0" if not present. Scores for all food items within a food group were summed across the items.

The data was analyzed using SAS version 8.01 (SAS Institute, Cary, N.C., 1999–2000). Statistical tests included Pearson's product-moment correlation coefficient, analysis of variance and

chi-square. Since the food intake data was not normally distributed, we used a logarithmic transformation of those variables in the analysis. Of the 274 families interviewed, complete data on food insecurity, household food supplies and child food patterns was available for 212 (table 1).

Of the 212 families studied, 39% were food secure; 45% food insecure without hunger; 13% food insecure with moderate hunger; and 3% food insecure with severe hunger. The sample was largely composed of less acculturated families, on the basis of preferred language (76.9% spoke mainly Spanish at home). Since a convenience sample was recruited for the study, the findings presented should not be generalized to the Latino population at large.

Impact on household food supplies

Food insecurity was associated with a decline in household supplies of both nutritious and less nutritious foods (table 2). For example, some nutrient-dense foods reported less often as food insecurity increased included oranges, apples, bananas, lemons, tomatoes, car-

rots, beef, fish and whole-wheat bread. A few less nutrient-dense foods, including soda, cookies, chips, powdered-chocolate flavoring and gelatin, were also reported less often as the level of food insecurity increased. Core foods — or those appearing in 90% or more of the households reporting food insecurity with hunger — remained stable and included corn tortillas, white rice, onions, beans and cooking oil (Kaiser et al. 2003). An important point for nutrition educators is that a number of high-fat and /or high-sugar foods also showed no change as the level of food insecurity increases; these included hot dogs (beef /turkey franks), sweetened (non-WIC) cereals, ice cream, candy and fruit-flavored punches.

The main source of food assistance in this sample was the WIC program (less than 10% reported using food pantries or other emergency food sources). Neither WIC nor food stamp participation was correlated with food security. This finding might be due to the nature of this cross-sectional study; a longitudinal design examining pre- and postenrollment food security status

TABLE 3: Correlation of household food-inventory food group scores to daily preschooler servings of the same food groups, based on food-frequency questionnaire

Food	Servings per day*	Correlation
Grains	8.0 ± 4.2	0.20‡
Fruit	2.3 ± 1.3	0.20‡
Vegetables	1.7 ± 1.4	0.28§
Meat	2.4 ± 1.5	0.17†
Milk	2.9 ± 1.4	0.17*
Snack foods	5.0 ± 3.0	0.21‡

* Mean ± standard deviation.

† $P < 0.05$.

‡ $P < 0.01$.

§ $P < 0.001$.



Schools and other programs providing food to low-income children should offer a wide variety of healthy foods that may not be available at home, especially fresh fruit and vegetables.

might yield a different picture. Also, our findings were basically unadjusted for several other unmeasured factors that may have influenced the decision to participate in those programs and confounded the results. WIC did not have an effect on specific household food items, even for the types of foods provided by WIC such as juice, milk, peanut butter, beans, cereal and eggs. However, WIC participation had a positive effect on the overall household inventory score for fruit (WIC households had 6.9 fruit items, versus 5.7 items in non-WIC households: $P = 0.04$). Having WIC coupons to cover some basic necessities may enable people to use the extra money saved to buy more fruit. Alternatively, WIC education may influence food-insecure households to purchase more fruit.

Children's eating patterns

As might be expected, a limited supply of foods in the household is correlated with lower child intake of those foods (table 3). For example, the number of different vegetables available in the household was significantly correlated with preschooler daily intake of vegetables ($r = 0.28$, $P < 0.001$). A similar relationship was found for other food groups. Even though parents may attempt to shield young children from hunger, preschooler food patterns are affected by changes in the household food supply. These changes may have important implications not only for current health status but also the long-term development of good eating habits in these children. For example,

research has shown that role modeling and repeated exposure to new foods is necessary to help children develop a preference for those foods (Birch and Marlin 1982). Limited household supplies of fruit and vegetables may reduce opportunities to learn to enjoy a variety of foods.

The food safety net

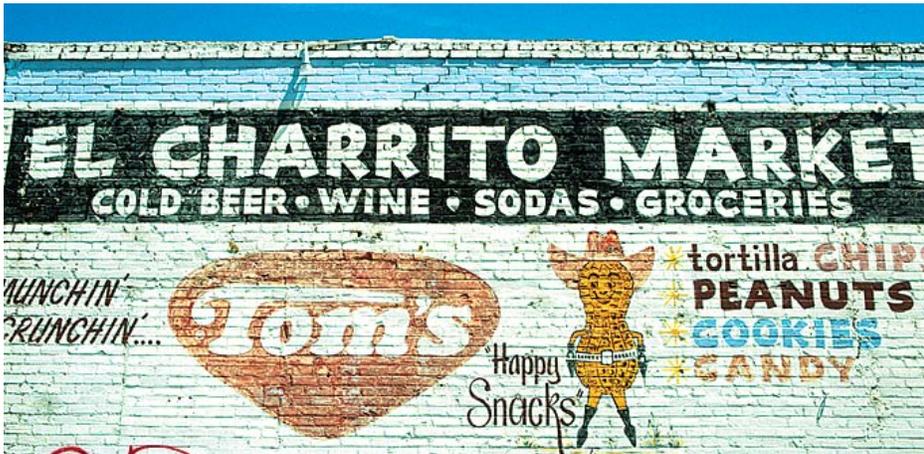
Although the most commonly reported foods in this study are similar to those reported by Latino families elsewhere (Beto et al. 1997), findings from our study, with its convenience sample, may not apply to other Latino groups. Emergency food providers should always check with their own clientele regarding the types of foods to provide. As a starting point, emergency food providers could focus on ways to provide commonly used foods that are most vulnerable to change in food-insecure households, such as fruits and vegetables including carrots, oranges, tomato products and apples. Other basic food supplies like flour, rice, pasta and beef might also be considered. On the other hand, supplies of some traditional items like corn tortillas and beans may already be adequate in the household stores and not necessary to provide through pantries.

Nutrition educators may also find the listing of foods in table 2 helpful in designing nutrition education programs. In our focus groups, migrant farmworkers identified lack of nutrition knowledge as a factor contributing to food insecurity. It is important to educate Latino families about the nutri-

tional benefits of inexpensive, traditional foods, such as beans, corn tortillas, lentils, oatmeal and cactus leaves. Educators should provide appealing recipes, making use of the foods most commonly found in food-insecure households. They can also increase awareness that certain inexpensive foods — such as hot dogs, instant noodle soups and fruit-flavored punch — have limited nutritional value. This education should be handled in a variety of settings, including the Expanded Food and Nutrition Education Program (EFNEP), the Food Stamp Nutrition Education Program (FSNEP), WIC, Head Start and other community programs.

Head Start, day-care centers and schools serving this population should offer menus that include a wide variety of nutritious foods commonly found in Latino homes. Since food-insecure families rely heavily on traditional foods at home, they may expect child care and school feeding programs to provide their children with foods that appear unaffordable to the family, especially fresh fruit, vegetables and meat. While nutrition programs are critical in providing children with access to healthful foods, they cannot replace parental role modeling and the home in the development of long-term eating patterns.

Although 78% of our study participants were enrolled in the WIC program, even more may have been eligible. Moreover, only 25% were receiving food stamps. Federal food-assistance programs should develop



When food insecurity increases, families may rely on high-calorie, low-cost foods to stave off hunger. Nutrition outreach and education to Latino families should focus on the benefits of inexpensive but healthful traditional foods such as corn tortillas, beans, lentils, oatmeal and cactus leaves.

more effective outreach and enrollment efforts to improve food security in this population.

In summary, food insecurity in Latino households is associated with a decline in household supplies of both nutritious and less nutritious food. In turn, household food supplies are correlated with preschooler food intakes in these families. A strong safety net must include strategies, through education and provision of nutritious foods, to support nutrition both inside and outside the home.

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Francisca Ramos, Nitza Rodriguez, Dennis Carrasquilla, Norma Molina, Mariana Castro, Anna Olivares, Martha Van Loan, Sharon Fleming, Ana Claudia Zubieta, Myriam Anaya, Nancy Keim, Gloria Espinoza-Hall, Dorothy Smith and Joanne Ikeda for their help in this research project. The UC Davis Economic Research Program Small Grants Program and the UC Division of Agriculture and Natural Resources funded this work.

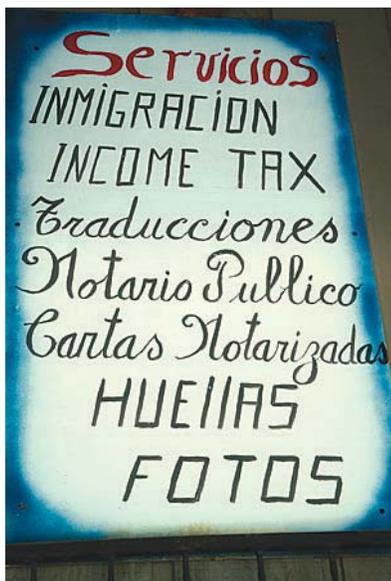
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Rural Latino families in California are missing earned income tax benefits

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When properly accessed, the federal Earned Income Tax Credit (EITC) can boost a family's yearly income by more than \$4,000. A study in Kern and Madera counties indicated that many, perhaps most, qualified low-income Latino families living in rural California communities may not be receiving the EITC. About 80% to 86% of eligible households nationwide receive the EITC, compared with about 36% of eligible California families in the study. The primary reason appears to be lack of accurate information and limited access to tax-preparation assistance. UC Cooperative Extension advisors and staff are well situated to provide information about the EITC.



Jack Kelly Clark

Tax-preparation services are often limited in rural communities.



The federal Earned Income Tax Credit (EITC) can boost a low-income family's yearly income by more than \$4,000. The credit aims to reduce poverty, promote work and help families build assets.

The Earned Income Tax Credit (EITC) has been described as the largest and the most successful federal assistance program for low-income working families with children. When properly accessed, it can boost a family's yearly income by more than \$4,000. More than 16 million U.S. low-income families received \$30 billion from this income supplement in tax year 2001. In 2001, the EITC elevated the families of 5 million children above the federal poverty line (Berube and Forman 2001). Implemented in 1975, the credit reduces poverty, promotes work, reduces income inequality, helps low-income families to build assets and encourages flexible resource utilization (Wirtz 2003; Cauthen 2002).

The original objective of the EITC was to offset payroll taxes, which disproportionately affect lower-income workers, and to supplement wages, encouraging work participation (Phillips 2001). Eligible families — those with incomes below 200% of the federal poverty line — that do not file for and receive the EITC are missing a valuable resource.

A unique characteristic of the EITC is its refundability. Eligible working parents are refunded any amount that remains after the credit offsets the worker's tax liability, or can receive the

full amount of the credit if they had no tax liability. Married workers with one qualifying child who earned less than \$30,201 in tax year 2002 received up to \$2,506 in additional income. Low-income married workers with two or more children, who earned less than \$34,178 in 2002, were eligible for up to \$4,140. Passage in 1996 of the federal Personal Responsibility and Work Opportunity Reconciliation Act, better known as "welfare reform," increased the importance of the EITC as a work incentive and wage supplement for the many families who were moved off welfare support to work in the low-wage sector (Greenstein 2002).

Who receives the EITC?

More eligible families receive the EITC than any of the traditional transfer programs, such as TANF (Temporary Assistance for Needy Families), Medicaid or food stamps. However, certain groups of qualified workers file for and receive the credit less often, including households with very low incomes, former welfare recipients and workers who speak a language other than English (Berube and Forman 2001). According to the 1999 National Survey of America's Families (NSAF), low-income Latino families nationwide are the least likely to

know about or to ever have received the EITC (Phillips 2001). Approximately three-fourths (74%) of low-income, non-Latino NSAF participants had heard of the EITC and about 50% had ever received it, whereas only about 32% of Latino parents knew about the credit and only 18% received it.

Moreover, despite the prevalence of low-income families in rural communities, the bulk of the EITC goes to urban and suburban workers (Berube and Forman 2001). Proportionately little of the credit makes its way to workers in remote locations. The rural locale itself may contribute to this skewed distribution by providing residents with less information about and access to programs that support work and enhance well-being.

We studied Latino low-income rural families in Kern and Madera counties, to develop quantitative data about usage of the EITC and qualitative information describing factors that affect access to the credit. We found that many, perhaps most, of these families were not receiving the EITC. About 80% to 86% of eligible households nationwide receive the EITC (Burman and Kobes 2002), compared with about 36% of eligible California families in our study.

Rural Families Speak Project

The Rural Families Speak Project (2004) is a multistate, longitudinal study currently in its fifth year, which is assessing changes in the functioning and well-being of rural families in the wake of welfare reform and associated reductions in programs and services. Beginning in 2000, researchers from 15 universities including UC began gathering annual qualitative and quantitative information about participants' financial and family well-being and program participation during intensive one-on-one interviews with mothers having at least one preschool-age child. A total of 414 interviews were conducted in the 15 participating states in 2000. We report on findings from this first wave of data collected from the California sample, and examine reported receipt of the EITC for the previous tax year (1999).

We interviewed 35 low-income Latino mothers living in rural Kern and Madera counties. Participating mothers were recruited through subsidized day-care programs and by word of mouth in three Central Valley communities, Delano, Wasco and Madera. Each family had a child of preschool age and



A survey of rural California families was conducted as part of the Rural Families Speak Project, a multistate effort to evaluate the impacts of welfare reform. Above, Martha López interviews a mother one-on-one about her family's financial status at the UC Cooperative Extension office in Madera County.

was eligible for (although not necessarily receiving) food stamps or vouchers through the Supplemental Nutrition Program for Women, Infants, and Children (WIC).

Latino mothers in the California sample averaged 28.5 years old (table 1; fig. 1). The majority were married or living with a partner (80%) and had two or more children (74.3%). Families often had one or more additional family members living with them. Participating mothers tended to be well educated. The majority of families also included at least one working parent. At the time of the first interview, 57.1% of the mothers and 89.9% of their partners were employed in low-wage work. The median family income was \$1,660 dollars per month, just under the poverty threshold for a household of five with two young children (US Census Bureau 2000).

TABLE 1. Demographic characteristics of California participants (n = 35)

	Mean	SD*	Median	Range	n	% sample
Age of mother	28.5 yrs	6.1 yrs				
No. children			2.0	1-5		
One					9	52.7
Two or more					26	74.3
No. family members in home			5.0	2-11		
Monthly income (\$)			1,660	5503-3103		

* Standard deviation.

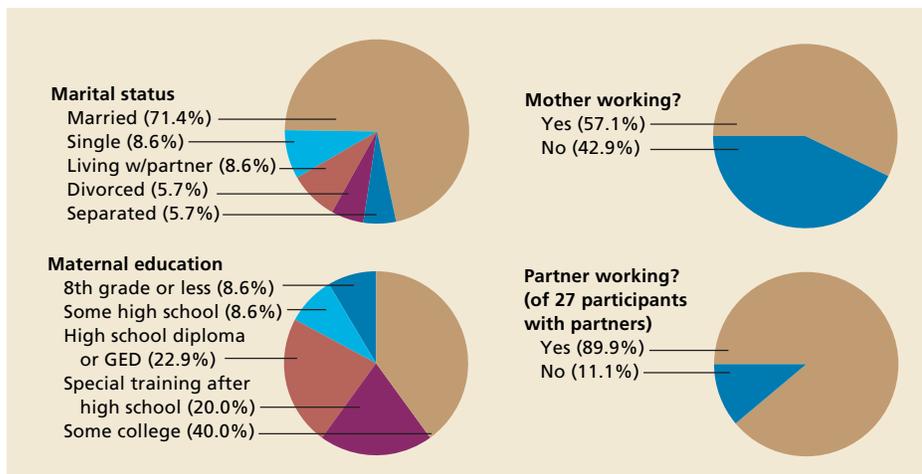


Fig. 1. Characteristics of California participants (n=35).

Rural Latino families and EITC

In order to be eligible for the EITC in 1999, workers had to be legal residents of the United States; earn wages during the tax year; have one or more natural or legally adopted children, legally placed foster children or stepchildren under age 18 living in the home; and have income less than 200% of the poverty threshold. According to these criteria, 33 of the Latino families in the study were eligible to file for and receive the EITC (table 2).

However, only 36% of the eligible rural California study subjects (n = 35) actually filed for and received the EITC in the previous tax year. The majority



Subjects lived in the Central Valley towns of Madera (Madera County), left, Delano and Wasco (Kern County). About 57% of the mothers and 69% of their partners were working, such as in the grape fields of Wasco, right.

of the eligible families (between 58% and 64%) failed to take advantage of the income supplement. About 85% of eligible families benefit from the EITC nationally. It appears that our findings — which indicate that significantly fewer eligible low-income Latino families living in rural California communities receive the credit — are supported by similar findings at the national level.

The qualitative data obtained by in-depth interviews provided insight into the issues affecting the use of the EITC by eligible families. Lack of or inaccurate information about the existence of, eligibility for and filing procedures was common. Language and cultural barriers further diminished the likelihood that Latino families knew about and accessed the credit.

Most eligible families in the study who were not receiving the EITC were unaware of its existence and applicability to their family situation. One mother gave a typical response. “I don’t know about that,” she said. “I think we always had to pay [taxes].”

Furthermore, study subjects who had heard of the EITC often had inaccurate information about how it works and their eligibility. Low-income workers often do not file a tax return when they believe they do not owe taxes or will not receive a refund. The refundability of the EITC means that eligible workers can receive the amount of the credit that remains over and above their tax liability — or the total amount of the credit if they owe no taxes. However, in order to receive the credit, workers with or without tax liability must file a federal return that includes specific paperwork (Schedule EIC).

Typical responses indicated that many subjects did not understand how the credit works. A 19-year-old mother

stated, “You have to be a certain age, I think, to get that.” In fact, the small EITC available to single, low-income workers without children is not available until the worker is 25 years old. There are, however, no age requirements for working parents with children who qualify — as long as the worker is not claimed as a dependent on their own parent’s tax return.

Often participants eligible for the EITC failed to file because they believed it was too much trouble or only applicable if they had tax liability to offset. These mothers understood that by filing income tax forms (such as the 1040EZ) with Schedule EIC they could receive a refund that included an amount of money over and above withheld taxes. But one typical participant said, “I don’t file taxes. That’s nothing but a hassle.” Furthermore, legal immigrant workers who are unfamiliar with the system or have language barriers and reduced access to qualified tax-preparation help may not understand that they are eligible for the EITC, even if their immigration status makes them ineligible for other public benefits.

Location, cultural and language issues, as well as limited education, may contribute to lack of knowledge and use

TABLE 2. EITC eligibility and participation, tax year 1999

Eligible for EITC	n	%
Yes	33	94.3
No	2	5.7
If eligible, received EITC		
Yes	12	36.4
No	19	57.6
Don’t know	2	6.0

age of the EITC. The isolation of rural areas (Fisher and Weber 2002) and possible linguistic isolation of Latino families may prevent adequate information from reaching qualified workers. In addition, research on strong cultural ties, utilizing the Michigan data from the same national study, identified the immediate and extended family as the main source of assistance and support. These strong ties limit efforts to access assistance from informal sources of support or contact with agencies and community resources.

Although programs that disseminate information about the EITC and encourage and assist eligible workers have been successful in metropolitan and suburban areas (Fleischer and Dressner 2002), there has been little effort to assist rural, low-income, multicultural workers.

Families living in urban areas have access to agencies that provide information on EITC as well as free tax-preparation assistance. Many of these agencies do not have offices in the small rural communities where the Latinos live. All of the 22 tax-preparation offices in Madera are for profit. The only free service is provided at the Madera County Library on a first-come



Only about 36% of the surveyed families who were eligible for the EITC applied for and received it in 1999. Outreach in rural communities is needed to ensure access to this important benefit for low-income workers and their children, above.

Lack of usage of the EITC may be just another example of how Latinos in rural areas are not accessing available public resources.

basis. In Kern County, there are few tax preparers in Wasco (one) and Delano (seven), while free tax-preparation services are provided in Bakersfield, the county seat 30 miles south. Even if an urban area is only a few miles away, rural low-income families often do not have cars and their access to public transportation may be limited. Often a family member voluntarily prepares income tax returns for multiple family members. While the family values this assistance, usually that individual is untrained in tax preparation and only uses the short form (IRS 1040EZ).

The Internal Revenue Service (IRS) recognizes that the EITC is underutilized by limited-resource families in rural areas and is looking for ways to improve outreach. One model, developed by Georgia Cooperative Extension, relies on active involvement of Cooperative Extension staff in providing information and offering free tax-preparation assistance (M. Rupured, University of Georgia, personal communication, 2003).

How can EITC access be improved?

Merely providing accurate information about the EITC may greatly increase usage by eligible families. IRS-provided information flyers about the EITC were sent to research participants in California after the first-year interviews. At year two, it appears that the percentage of eligible families who received the credit more than doubled.

Even when qualified workers file for and receive the credit, several factors can interfere with their receipt of the maximum amount of money for which they are eligible. Tax-preparation and loan fees are eroding the benefits of the EITC. Many low-income workers who believe they would not be able to accurately prepare their federal and state tax returns go to preparers who charge as much as \$100. In addition, many of these preparers encourage clients to get the money right away by taking out a refund anticipation loan (RAL) with fees as high as \$90 to \$300 (Kim and Berube 2003). As a result, in 2002 about

\$2 billion that was intended to benefit low-income families went directly to commercial tax preparers and affiliated national banks (Kim and Berube 2003). Programs that provide free or low-cost tax-preparation assistance, encourage and assist low-income workers to obtain bank accounts (for faster electronic refunds from the IRS) and promote consumer awareness about the extreme costs of RALs can reduce these tendencies and decrease out-of-pocket tax-preparation costs (Kim and Berube 2003).

Our study findings clearly indicate the need for informational programs that reach out to rural communities, providing accurate information about the existence of the tax credit, eligibility, tax-preparation procedures and availability of low-cost or free tax-preparation assistance. Each year the IRS provides good bilingual information regarding the EITC in an effort to reach eligible families. Currently, EITC information is being included as part of many Expanded Food and Nutrition Education and Food Stamp Nutrition Education program efforts in California. Unfortunately, these programs do not have the capacity to reach all rural areas. To provide increased coverage, UC Cooperative Extension's Spanish Broadcast and Media Services provides this information in written and oral formats. Providing the information helps increase the number of families utilizing this credit. The challenge is to utilize our many networks to reach Latino families in rural areas.

Underutilization of all public resources was a notable trend among the study participants. The lack of usage of the EITC may be just another example of how Latinos in rural areas are not accessing available resources. While providing information on the EITC will help, improving overall access to public benefits for limited-resource Latinos is a larger issue that must be addressed.

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Health Services, Sacramento; and M.L. López is Nutrition, Family and Consumer Advisor, UC Cooperative Extension, Ventura County. This research was supported in part by USDA/CSREES/NRICGP Grant-2001-35401-10215. Data was collected in conjunction with the cooperative multistate research project NC-223, Rural Low-income Families: Monitoring Their Well-being and Functioning in the Context of Welfare Reform. Cooperating states are California, Colorado, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New York, Ohio, Oregon and Wyoming.

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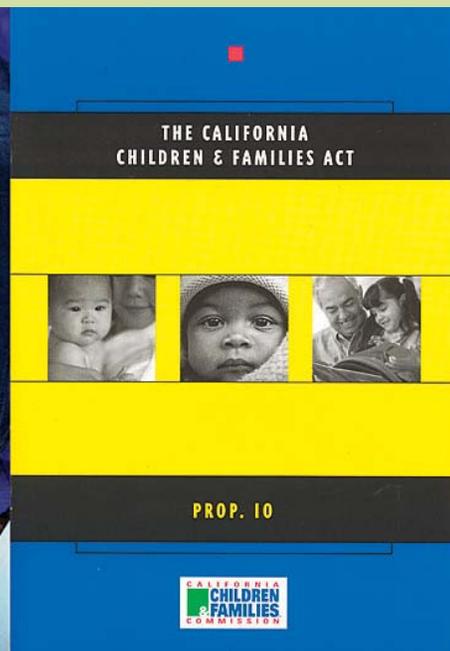
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Project engages culturally diverse parents in Proposition 10 decisions

David Campbell
Joan Wright

California's Proposition 10, a tax on tobacco products passed in 1998, provides counties with funds to improve the health, education and school readiness of children up to age 5. A foundation-sponsored Civic Engagement Project (CEP) seeks to promote inclusive participation in Proposition 10 decisions by engaging a broad spectrum of parents and other community members. Based on our systematic evaluation of the CEP's initial years of work, we describe six different civic engagement tools adopted by counties, strengths and weaknesses of each, and what we learned about the conditions under which they are most effective. The results illuminate a key public challenge — how to welcome culturally and linguistically diverse Californians as active and valued participants in local civic processes while obtaining meaningful guidance for decision-making.

California's increasing class disparities and cultural and linguistic diversity place new strains on public institutions (Baldassare 2000). The full spectrum of the state's citizens should be engaged in community governance processes so that new voices are heard



Yolo County Children & Families Comm.

Proposition 10 taxes tobacco products to improve the health and school readiness of children 5 years old and under. County-based commissions decide how to distribute the funds. *Left*, a young boy visits a booth hosted by the Yolo County Children and Families Commission at the county fair; the commission's theme was "Read, Talk and Play With Your Child." *Right*, Proposition 10 guidelines and information.

and public services reflect the needs and concerns of all groups. The political science and public administration literatures describe numerous tools for promoting public deliberation including issue forums (Button and Mattson 1999; Mathews 1994), deliberative polls (Fishkin 1991, 1995), citizen juries (Crosby et al. 1986; Kathlene 1991; Renn et al. 1993) and representative survey panels (Nagel 1992; Weeks 2000). However, these tools are frequently criticized as insufficiently inclusive, failing to reach beyond those who are already active and informed (Nagel 1992). Whether citizen participation is viewed primarily as an aid to improving public programs (Epstein et al. 2002) or as an ethical ideal (Denhardt and Vinzant 2000), addressing this shortcoming should be a high priority.

Partnership for civic engagement

In November 1998, California voters passed Proposition 10, a state ballot initiative that taxes tobacco products to

create a multibillion-dollar revenue stream for improving the health and school readiness of children up to age five. Commissioners in each of California's 58 counties decide how local funds (apportioned by birth rate) are spent and how the state-required public input is obtained and incorporated. Beginning in 1999, five California foundations interested in civil investing and eight county-based Children and Families Commissions teamed up to form the Civic Engagement Project for Children and Families (CEP). The CEP augmented commission resources so that a broader spectrum of the public could be involved in local Proposition 10 planning. The local participants — known variously as "Proposition 10 Commissions," "Children and Families Commissions," or, more recently, "First Five Commissions" — are in Contra Costa, Monterey, San Diego, San Francisco, San Mateo, Santa Clara, Santa Cruz and Yolo counties.



Carmen Garcia (left), Yolo County’s community engagement coordinator, and AmeriCorps member Aida Silva conduct prekindergarten assessments during a fair at the Prairie Elementary School in Woodland.

Recognizing that civic engagement must be tailored to local conditions, CEP staff did not dictate a single approach for the participating commissions. Instead, they asked each to hire its own civic engagement coordinator and gave them considerable discretion in how to use CEP funds. The only requirement was that the activities meet three guiding principles:

- (1) Inclusive participation, particularly to ensure that lesser-heard voices are involved.
- (2) Civic dialogue, aimed at stimulating ongoing discussion, mutual respect, a sense of common ground and an ongoing network to support children’s issues.
- (3) Policy effectiveness, defined as evidence that inclusive dialogue influenced commission decisions or catalyzed community initiatives to improve the lives of young children.

Having created the eight civic engagement “laboratories,” the funders hired an evaluation team led by the UC Davis California Communities Program to describe how each county interpreted and implemented the guiding principles, and to report on the successes and problems encountered from the perspective of CEP stakeholders. From 1999 to 2002, the authors led the evaluation team and conducted interviews with CEP funders and project staff, as well as local commissioners, commission executive directors, civic engagement coordinators and other staff. UC Cooperative Extension (UCCE) observers provided background on their local communities and

along with the authors observed a sample of local civic engagement activities using common protocols. Retrospective interviews were conducted with public participants in commission meetings and activities. Latinos were the largest non-English-speaking group in the eight counties, followed by Asians. We conducted 32 participant interviews in Spanish, but none in the Asian languages due to limited resources and the wide array of languages spoken. Across the eight counties, the evaluation team observed 148 public meetings and conducted 344 semi-structured interviews (table 1).

Our evaluation was limited by many factors. By its nature, the meaning of “inclusive civic engagement” is open to interpretation. Various stakeholders differed in their understandings of the concept, both within and between counties. Furthermore, we found civic engagement activities to be characteristically protean, shifting form due to the changing priorities of local commissions, changing understandings of what CEP funders wanted, or changing impressions of what was happening on the ground. As a result, our evaluation could not definitively measure the degree of inclusivity against some pre-established and widely held standard (since none exists), nor could it easily compare civic engagement results across local contexts or cultural subgroups since both the “treatment” and the context varied considerably. Another limitation was that we were not involved long enough to determine whether the implemented activities would be sustained over time.

TABLE 1. Evaluation activities by county

County	Meetings observed	Commissioner and staff interviews	Total participant interviews (no. in Spanish)
Contra Costa	22	10	36 (5)
Monterey	18	11	27 (0)
San Diego	19	10	26 (0)
San Francisco	10	14	29 (1)
San Mateo	10	15	22 (4)
Santa Clara	14	16	29 (4)
Santa Cruz	29	15	52 (18)
Yolo	26	12	20 (0)
Total	148	103	241 (32)

Variations in local context

The eight counties varied widely in factors such as demography, political culture, previous history of collaboration, economic conditions, funding base, number of non-English-speaking groups, and skills and continuity of civic engagement staff (table 2). The five CEP funders made grants of \$60,000 to \$100,000 per year available to each participating commission. These funds were used to hire a local civic engagement coordinator; engage temporary consultants such as bilingual translators and media consultants; develop outreach materials; pay for food, child care and other costs of community meetings; and in some cases provide stipends for community participants. Larger commissions supplemented CEP funds by hiring outreach workers, and often had an easier time attracting and retaining experienced civic engagement staff.

Counties with just one or two sizable non-English-speaking groups had a certain advantage in using CEP funds. For example, Santa Cruz could confine its bilingual work to its large Latino community, while commissions in Contra Costa, San Francisco, San Mateo, Santa Clara and Yolo counties had to reach out to nine or more linguistic subpopulations, such as Spanish, Cantonese, Vietnamese, Mien, Laotian, Russian and users of American Sign Language. Most commissions translated documents into Spanish and employed Spanish-speaking staff; a few held meetings or translated materials into other languages. Commissions also in-

TABLE 2. Economic and demographic variation in CEP counties

County	Population	Prop 10 funds 1999-00	Non-English-speaking groups*	Whitet	Latino	Asian	African American	Per capita income†	Child poverty rate‡
		\$ millions		%					%
Contra Costa	932,000	12.8	12	66	13	11	9	5	14
Monterey	390,900	7.0	3	47	38	8	6	14	24
San Diego	2,833,500	45.0	4	61	24	8	6	17	20
San Francisco	797,200	8.5	9	41	16	33	10	2	21
San Mateo	727,300	10.5	9	54	21	20	5	3	9
Santa Clara	1,717,600	27.5	10	51	23	22	4	4	14
Santa Cruz	253,400	3.7	1	71	23	4	1	9	19
Yolo	158,900	2.2	11	86	22	9	20	17	22
Statewide	34,036,000	546.0	8	52	29	11	7	-	23

* Number of languages other than English spoken by 1% or more of the English learners in the county's public schools.

† Percentage of total county population in each category.

‡ County ranking of all 58 California counties by per capita income.

§ Estimated percentages of people under 18 in poverty in California.

Sources: California Department of Finance 1999 (population); California Legislative Analyst Office 2002 (Proposition 10 funds); California Department of Education 2002 (languages spoken); California Department of Finance 1997 (racial/ethnic makeup); US Department of Commerce 1997 (per capita income); US Census Bureau 2001 (poverty rate).

involved English-speaking groups that are considered less likely to participate in local planning processes, such as blacks, Native Americans, Asian-Pacific Islanders, parents of children with special needs, homeless families and incarcerated parents.

Civic engagement tools

The eight counties implemented a variety of civic engagement “tools” — coordinated activities designed to foster inclusive participation in the work

of the commission (table 3). The following sections describe the six most significant tools, their strengths and weaknesses, and our working hypotheses about the conditions needed for the tool to be most effective.

Advisory committees. Advisory committees are a familiar form of citizen participation, and under Proposition 10 guidelines each county must designate at least one such body. But because recognized expertise is often a qualification for selection, advisory

committees typically attract those already engaged at the expense of lesser-heard voices. The CEP prompted experiments to move beyond this status quo, altering the nature, composition and functions of particular advisory groups.

For example, San Diego’s commission created a technical and professional advisory committee whose 15 members represent well-known service providers to make formal recommendations to the commission. To ensure that

this committee was informed by citizen voices, one meeting per quarter was rotated among different regions of the county and ended with an open community conversation designed to inform the committee of community concerns and increase awareness about Proposition 10. The commission also developed a separate layer of advisory structures called leadership teams to solicit advice on key commission initiatives. These teams elicited greater involvement of parents, and operated less formally since they reported to the executive director and not the commission, avoiding constraints imposed under the Brown Act (California’s open meeting law).

Across the CEP counties, the more formal the advisory structure, the more power it

TABLE 3. Major civic engagement tools used by CEP counties

Tool	Nature	Strength	Weakness	Counties 1999-2002
Advisory committees	Provide advice to commission	Potential for substantial influence over decisions	Typically engages experts rather than new parent voices	All
Outreach workers	Build relationships with segments of community	Often effective at overcoming language and cultural barriers	Community connection can come at expense of influence with decision-makers	Contra Costa Santa Cruz Santa Clara Yolo
Community conversations	Facilitated public discussions on community issues	Nonthreatening space for hearing parents’ concerns, sharing information, building relationships	Nonthreatening meetings can preclude substantive policy discussions	All
Community capacity-building	Develop local leaders and orgs. to help achieve outcomes	Intensive focus on few leaders/organizations can have snowball effect on others	Directly engages small no. individuals with few short-term payoffs	San Mateo San Diego
Minigrants	Provide small grants to nontraditional recipients such as parent groups, neighborhood orgs.	Parents and community groups can complement approaches of existing agencies or pursue innovative approaches	Difficult to implement due to contracting and liability rules, red tape	San Francisco Santa Cruz
Program design workgroups	Involve citizens directly in design of commission programs	Highly deliberative, gives parents power over major commission expenditures	High demands on staff to recruit and train parent participants within bureaucracy	Santa Clara

tended to have, and the less likely it was to invite the regular participation of parents and community members. Conversely, less formal advisory structures were more likely to provide a welcoming setting for diverse participants, but tended to have less direct influence on commission decisions.

Our work identified the following working hypotheses regarding the conditions required for advisory committees to promote inclusive citizen participation:

- The commissioners are willing to entertain advice and/or to delegate part of their decision-making power to an advisory committee.
- There are clear agreements as to the committee's function, membership and role, such as whether it can make formal recommendations to the commission.
- Interests and experiences of a broad array of providers and community members are represented, giving the committee public legitimacy.
- Persons selected understand the content and process issues sufficiently to engage in informed deliberation.
- A safe and welcoming environment is created for discussion and continued learning, so that newcomers are not intimidated.

Outreach workers. Typically, commissions hired outreach workers with some previous history of community involvement to build relationships and connections with particular segments of the community — ethnic, class, neighborhood or special interest. For example, eight outreach workers in Santa Cruz, most bilingual Spanish-speakers, conducted intercept interviews at locations like migrant housing units, preschools, shopping malls and grocery stores. Contra Costa deployed a Spanish speaker to work in the heavily Latino east county area and a popular pastor to work in predominantly black Richmond. Santa Clara hired and trained 15 outreach specialists to target different ethnic groups and community sectors, such as the faith community and gay or lesbian parents.

In general, outreach workers were effective at overcoming language and cultural barriers and promoting more



Yolo County Children & Families Comm.

A group of foundations funded a civic engagement project to promote diverse participation in decision-making regarding how Proposition 10 funds are spent. Children visit the Yolo County commission's fair booth.

inclusive participation. On the other hand, we heard frequent mentions of a perceived disconnect between outreach work and the actual deliberations of the commissions. Local civic engagement staff often described themselves as caught between two different worlds, one heavily bureaucratic and formal and the other idiosyncratic and dependent on trusting personal relationships.

The CEP experience suggests several conditions required to effectively deploy outreach workers as a civic engagement tool:

- The commission can identify the community segments in need of an outreach worker, and commit sufficient funds to hire qualified individuals.
- Staff and outreach workers combine community respect and local knowledge with an understanding of the commission and its processes, and credibility with commissioners.
- Staff training and supervision are provided.
- Criteria are developed for determining the success of outreach worker efforts.

Community conversations. At the urging of CEP project staff, all counties experimented with some form of community conversation. This tool consists of episodic meetings designed to include a diverse set of parents and community members. Community conversations are primarily intended as an accessible en-

try point into the work of the commissions, rather than a vehicle for direct input into decisions. For example, Contra Costa's commission convened a series of regional community conversations centered on the question, "How can we make Contra Costa a better place for families with young children?" The meetings were intended to provide commissioners with new program ideas and to give community participants the opportunity to learn about Proposition 10, apply for commission funds, become involved with commission committees or become advocates for children. Two meetings (1 week apart) were held in each of the four county regions. Commission staff arranged child care and dinner and simultaneous English-Spanish translation where necessary. Outreach techniques included invitations (in English and Spanish) on the commission's mailing list; articles in local mothers' club newsletters; recruitment by community agencies and child-care centers; advertising in the local newspaper; and existing e-mail networks.

Hiring outreach workers with credibility in their communities appears to have contributed to attendance (40 to 60 diverse participants per meeting), as did the incentive of a \$40 gift certificate for attending both sessions. The use of the fiscal incentive was unique to Contra Costa County; therefore, we have no comparative basis for ascertaining how large a role it played in facilitating the

involvement of lower-income parents.

The meetings we observed demonstrated the value of encouraging broad participation and listening to everyone with respect. Participants said the meetings made them aware of previously unknown services and of the concerns of parents in social circumstances different from their own. On the other hand, these cross-class encounters were at times jarring, as when two women we interviewed from wealthy neighborhoods indicated that they felt out of place at a meeting dominated by concerns over unsafe parks and drug dealing.

Staff using community conversations faced one recurring choice: whether to convene groups that were homogeneous or heterogeneous. Some opted for working primarily with groups that shared a history of working together, or some bond of ethnicity, culture or language. Others, like Contra Costa, attempted to gather diverse publics for conversation. While the latter seems preferable from the standpoint of deliberative ideals, most staff actually preferred the former, since it tended to be more appealing to parents unfamiliar with public meetings, especially among immigrant populations.

The features of community conversations that are critical to supporting inclusive and deliberative participation include:

- Staff ensures that the issue-related conversations are framed, convened and facilitated appropriately, and that food, child care and translations are provided as needed.
- Follow-up opportunities allow interested individuals to become involved.
- Comments, concerns and information are accurately and sensitively recorded and conveyed to participants and decision-makers.
- The commission does not ignore the feedback, but carefully considers it.
- Citizen participants are kept informed about what is happening to the ideas they offered and any resulting commission decisions or tangible outcomes.

Community capacity-building. This form of civic engagement seeks to develop local leaders and organizations



Young children benefit from programs that promote school readiness in a fun environment. Proposition 10 encourages parents to be active and informed participants in deciding what types of programs their children need. Clockwise from upper left, at the Winters library, a grandmother reads a book purchased with minigrant funds awarded to Friends of the Library; a boy hits a piñata at the Esparta Cultural Fair, also funded by the Yolo County commission; and preschool children read books in Spanish and practice "life skills."

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whose assets help the commission achieve intended outcomes and whose approaches model promising practices of civic engagement. San Diego's commission contracted with the Consensus Organizing Institute (COI) of California State University, San Diego to develop community leadership in three pilot collaboratives. In each, a core group of six to 10 parents identified by the COI organizer met weekly and then reached out to involve other parents (such as by creating service directories and holding school-readiness forums). The COI approach emphasizes careful and patient nurture of self-selected parent leaders who are willing to invest time and energy. The theory is that intensive focus on a few citizen leaders will create a snowball effect that promotes more widespread participation.

San Mateo's commission conducted more than 91 public dialogues regarding early childhood issues in partnership with the Peninsula Conflict Resolution Center. Their purpose was not to influence commission decisions, but rather to develop individual leaders to advocate for young children. In engaging San Mateo's target audience — Latina women with little previous connection to public affairs — staff spent their time cultivating trust and personal relationships, one at a time. In

their understanding, "a dialogue is an intense personal encounter with someone you trust," rather than a formal deliberation about public issues.

Here is a partial list of elements that go into designing an effective community capacity-building strategy:

- The commission partners with an existing community organization or uses its own staff.
- Whoever leads the capacity-building effort strikes a balance between being supportive and being directive.
- Parents and other community members identify roles they can play to make a difference.
- Parents and other participants learn by doing and gain skills, knowledge, experience and confidence.
- Recognition of community partners by the commission is frequent and perceived as genuine.

Minigrants. Minigrants are awards of \$500 to \$10,000 that go to nontraditional recipients, such as parent groups, small neighborhood organizations or home-based child-care providers. For example, Santa Cruz awarded 40 minigrants of up to \$10,000 to family child-care providers to purchase equipment and materials. Outreach workers helped publicize the grants and hosted workshops. Recipients were grateful to

the commission for reaching out to people who had never previously received public funding.

The San Francisco commission's Parent ACTION (Achieving Change Together in Our Neighborhoods) grant program took the additional step of creating a parent selection board with the authority to recommend proposals. Also, the application process was simple and accessible with ample technical assistance (10 formal workshops plus individual assistance). As a result, the selection board, applicants and funded programs were widely perceived as representing the diversity of San Francisco's population in terms of race, ethnicity, neighborhoods and language spoken.

San Francisco commission staff discovered that genuine efforts to share power with citizens take more staff time and energy rather than less, and representatives of funded programs reported that procedures for getting funds from the city were cumbersome and challenging. Staff had to help project leaders adjust to the city grant process and vice versa, and spent considerable time negotiating contractual and reporting agreements.

The conditions required to implement minigrants as an effective citizen participation tool include:

- Staff has the ability to simplify the application process and help neophytes.
- Staff can convince bureaucrats to adapt their usual expectations regarding insurance, reporting and accountability to the realities of a small grants program.
- There is capacity to encourage applications in languages other than English.
- The commission staff can find a balance such that sufficient proposals are attracted, but not so many that the rejection rate creates bad will in the community.

Program design workgroups. The most ambitious civic engagement strategy we observed involved citizens directly in the design of commission-funded initiatives and programs. The Santa Clara commission stipulated that major Proposition 10 funding would be directed by regional partnerships with at least 51% of their membership from

parents and non-agency-affiliated community members rather than from provider groups. When this condition was met, the partnerships had autonomy to create a community-based plan that spent up to \$2 million over a 3-year period.

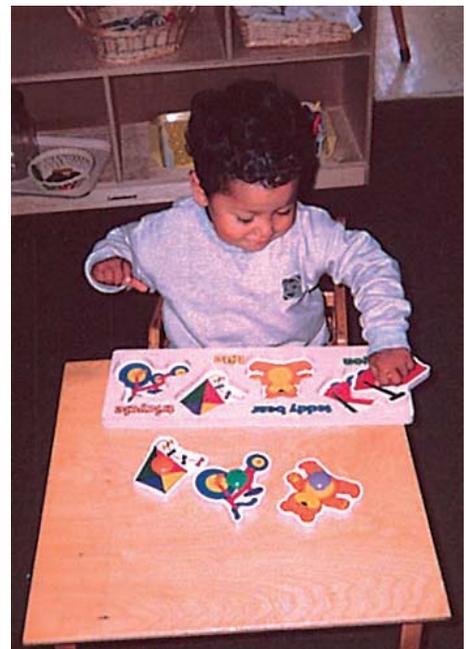
This form of citizen participation is highly deliberative and clearly linked to commission funding decisions. In Santa Clara's case, a representative group of local citizens — and the broader group of citizens from whom they gather input — was empowered to play a critical role in deciding how millions of dollars were spent. Program design workgroups are effective citizen participation tools when:

- The local political culture and commission support power-sharing with citizens, and back their commitment with significant funding.
- Staff can invest the extra time required to orchestrate meaningful involvement of community members in the complicated design process.
- Community members are sufficiently convinced that their voices will be heard so that they are willing to commit time and energy.
- Commission requests for revisions of design workgroup proposals are clearly explained with a chance for the group to defend its ideas.
- Participants are informed of the final product of their work, and recognized for their contributions.

Engaging diverse parents

The CEP successfully created rich laboratories for learning about civic engagement practices in culturally diverse settings. As of November 2003 the eight-county project was still under way, and it has begun to influence how other California counties are engaging new and often unheard voices in policy development. With respect to the three guiding principles, several significant CEP outcomes can be reported.

Inclusive participation. All the local commission partners conducted special outreach to diverse groups in many locations, made possible by CEP funds supporting culturally appropriate and bilingual outreach staff, translation services, child care and food. Low-income parents, teen parents, parents who are



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Some commissions fund minigrants to nontraditional recipients such as local parent groups and neighborhood organizations. In Yolo County, child-care providers received money to purchase age-appropriate developmental tools.

not English speakers, and others not usually involved participated in public meetings and planning processes.

Civic dialogue. The CEP was successful during its first and second years in promoting community meetings open and respectful of diverse publics. These "exploratory dialogues" aired a range of perspectives and enhanced mutual understanding. It was more difficult to encourage framing practices that identified issues facing the commission for community discussion, or to implement "deliberative dialogues" where differences were probed and conflicts surfaced, or where there was a sustained effort to work through disagreements or tradeoffs to generate specific policy advice for commissioners.

Policy effectiveness. While it was not the major factor influencing commission decisions, civic engagement yielded some marginal impacts, such as agreements to fund minigrants, and increasing investments of the commission's own funds to support civic engagement staff. While funders and their local partners seemed satisfied with these limited policy results, we were reminded again of how difficult it is to build civic processes that are simultaneously inclusive, deliberative and politically effective. Seeing how far short of that ideal the well-funded and often

We observed a tendency to treat diverse participation as an end in itself, rather than as an important step toward more effective community governance and better outcomes for children.

heroic CEP efforts fell adds credence to the conventional wisdom that it is difficult for Californians to establish common ground in the face of cultural diversity. Apparently, this is even true in policy arenas like children's issues in which there is widespread agreement about the need to act.

Our evaluation suggests three overarching lessons. First, the most important variable in a civic engagement process is the quality of the staff and leaders — their skill, commitment and persistence. All civic engagement work is labor intensive and nonroutine, and parents of young children are something of a moving target since their concerns change rapidly as children grow up. Civic engagement staff must blend local knowledge, clarity about purposes, sensitivity to diverse populations and the ability to both listen and lead. Critical factors include how many staff are employed full-time, how well they are paid and supported, how much experience they have and how well their style and backgrounds fit in the local context. Ideally, local staff should be conversant in multiple tools for civic engagement, learning to mix and match them depending on the desired outcomes.

Second, less obvious but extremely important, is the need to be clear about why inclusive and diverse participation is sought. We observed a tendency in these experiments to treat diverse participation as an end in itself, rather than as an important step toward more effective community governance and better outcomes for children. The potential purposes of inclusive participation include clarifying areas of conflict and consensus given group distinctions, promoting greater use of sometimes underutilized public services, increasing the legitimacy of the decision-makers in all community segments and encouraging community "do it yourself" efforts.

Finally, to engage parents as citizens, their involvement can be viewed in a variety of guises, whether as ratio-

nally informed participants serving on committees and taking part in community discussions; as customers giving feedback on services received; or as citizen problem-solvers acting to improve the lives of young children. In pursuing strategies to enhance these types of involvement, we must never forget that all parents, regardless of their degree of civic engagement, are already playing a critical and ongoing role as the de facto "frontline service providers" most responsible for educating the state's future citizens.

Note: The full CEP evaluation report is at: www.ccp.ucdavis.edu. For more information about the CEP, go to www.civicengagementproject.org.

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Lucile Packard Foundation, James Irvine Foundation, Miriam and Peter Haas Fund, Peninsula Community Foundation and Walter and Elise Haas Fund.

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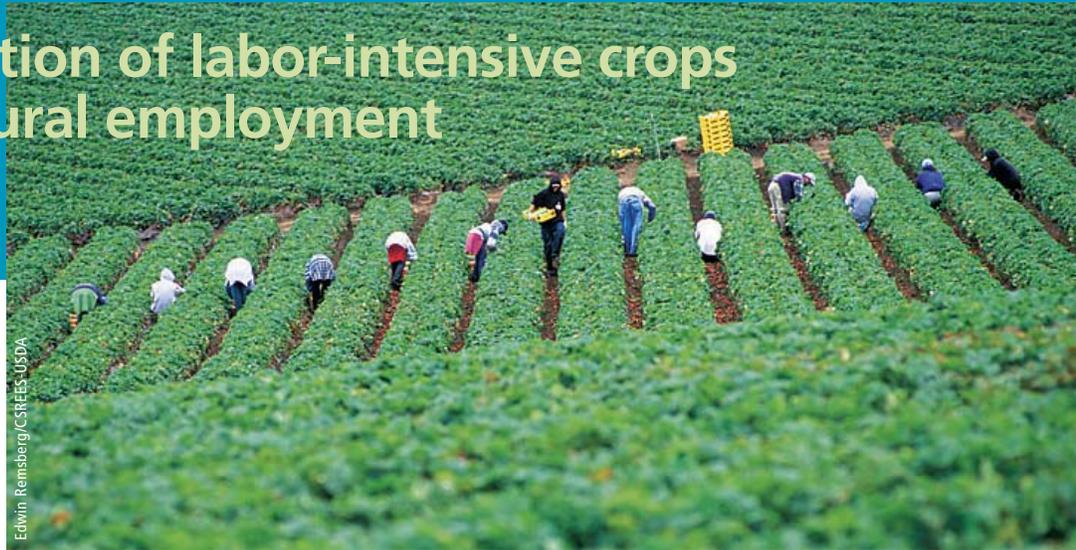
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Expanded production of labor-intensive crops increases agricultural employment

Akhtar Khan
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The production of labor-intensive fruit, vegetable and horticultural specialty crops increased in the 1990s, as did the employment of farmworkers: average annual employment or roughly the number of year-round equivalent jobs rose about 20%, to almost 400,000. Far more individuals, however, are employed on California farms during the year. Agricultural employers reported 1.1 million individuals (unique Social Security numbers) when they paid unemployment insurance taxes in 2001. We analyzed the jobs and earnings of these farmworkers in 1991, 1996 and 2001. About three individuals were employed for each year-round equivalent job in the 1990s, and there was a shift to farmers hiring workers via farm labor contractors. The findings suggest that it may be possible to employ a smaller total farm workforce, with each worker employed more hours and achieving higher earnings.

California has the largest and most complex agricultural labor market in the United States, reflecting seasonal employment demands, the predominance of immigrant workers and the significant role of labor contractors in matching workers and jobs. Whether measured in sales, production or acres, California agriculture expanded in the 1990s (table 1). Farm sales reached \$27 billion in 2000, with about 77 million tons of crops produced on 8.8 million acres. More than half of these sales (with 49 million tons of produce on 3.8 million acres) were in fruits and nuts, vegetables and melons, and horticultural specialties (FVH), such as flowers and nursery products. Rising yields



Labor-intensive crops such as fruits and nuts, vegetables and melons, and horticultural specialties now account for more than half of California farm sales. An analysis found that 1.1 million workers are doing the equivalent of 400,000 year-round agricultural jobs in California. In Watsonville, farmworkers harvest strawberries.

meant that more tons of vegetables were produced from the same acreage, while acreage of fruits and nuts rose from 2 million acres in 1990 to 2.4 million acres in 2000, a 19% increase over the 1990s.

Many FVH commodities are labor intensive, with labor accounting for 15% to 35% of production costs. Most of the workers employed on FVH farms are immigrants from Mexico, and a significant percentage are believed to be unauthorized (fig. 1).

In recent years, several proposals have aimed to reduce unauthorized worker employment in agriculture (see page 4). In September 2001, Mexican President Vicente Fox called for a U.S.-Mexico labor migration agreement so that "there are no Mexicans who have not entered this country [U.S.] le-

gally, and that those Mexicans who come into the country do so with proper documents. Regularization does not mean rewarding those who break the law. Regularization means that we give legal rights to people who are already contributing to this great nation." President George Bush agreed: "When we find willing employer and willing employee, we ought to match the two. We ought to make it easier for people who want to employ somebody, who are looking for workers, to be able to hire people who want to work" (Migration News 2001).

The United States and Mexico appeared close to agreement on a program to legalize farm and other workers before September 11, 2001. However, after the war on terror was declared, the momentum for a new

TABLE 1. Harvested acres of California crops, 1991–2000

Year	Field crops		Fruits and nuts		Vegs and melons	
	Acreage	Production	Acreage	Production	Acreage	Production
		tons		tons		tons
1990	5,233,715	25,141,401	2,002,650	13,051,525	1,185,790	21,149,460
1991	4,750,498	24,245,313	1,998,900	11,053,475	1,099,764	21,770,010
1992	4,926,284	24,731,653	2,012,500	13,492,350	1,061,976	18,659,660
1993	4,693,600	24,238,996	2,047,700	13,403,875	1,223,556	21,795,467
1994	4,913,800	25,980,008	2,092,350	13,748,800	1,327,502	25,047,912
1995	4,910,200	25,353,756	2,094,470	12,474,300	1,289,906	23,556,849
1996	5,029,000	25,276,521	2,155,050	13,112,150	1,382,228	25,252,871
1997	5,292,499	28,096,228	2,211,070	15,419,680	1,243,758	23,377,219
1998	5,161,274	26,875,266	2,249,650	13,359,825	1,351,526	28,028,170
1999	5,160,073	28,652,304	2,321,400	12,791,700	1,459,396	34,543,286
2000	5,035,220	28,528,069	2,383,760	15,486,300	1,380,064	33,077,470
1990–96	-3.9%	0.5%	7.6%	0.5%	16.6%	19.4%
1996–00	0.0%	13.0%	11.0%	18.0%	0.0%	31.0%

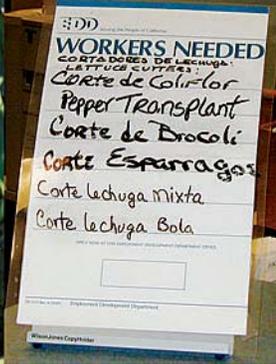
Source: CASS 2002.



Edwin Remsburg/CSREES-USDA



Edwin Remsburg/CSREES-USDA



The authors argue that the efficiency of the farm labor market could be improved so that fewer workers are each employed more hours and achieve higher earnings. *Left*, begonia bulbs are produced in Marina. *Center*, Angelberto

Sanchez prunes orange trees at the UC Lindcove Research and Extension Center in Exeter. *Right*, the California Employment Development Department (EDD) connects workers with jobs in Calexico, free of charge.

guest-worker program and the legalization of immigrants already in the country slowed. In summer 2003, there were several new proposals for a migration agreement with Mexico to legalize the status of currently unauthorized workers and allow some to earn immigrant status by working and paying taxes in the United States. There is little agreement, however, on what impacts such a program would have on California's farm labor market.

We used a unique database to examine farm employment trends in California agriculture. The data suggests that: (1) about three individuals are employed for each year-round equivalent job, helping to explain low farmworker earnings; (2) there was a shift in the 1990s from crop farmers hiring workers directly to farmers hiring via farm labor contractors (FLCs); and (3) there is considerable potential to improve farm-labor market efficiency, by using a smaller total workforce with each worker employed more hours and achieving higher earnings.

Average, peak and total employment

California employers who pay \$100 or more in quarterly wages are required to obtain an unemployment insurance (UI) reporting number from the California Employment Development Department (EDD). The EDD then assigns each employer or reporting unit a four-digit Standard Industrial Classification (SIC) or, since 2001, a six-digit North American Industry Classification System (NAICS) code that reflects the employer's major activity (US Census Bureau 2002). Major activities are grouped in increasing levels of detail;

for example, agriculture, forestry and fisheries are classified as a major industrial sector and, within this sector, SIC 01 is assigned to crops, 017 to fruits and nuts and 0172 to grapes.

We defined "farmworkers" as unique Social Security numbers (SSNs) reported by farm employers to the EDD, and then summed their California jobs and earnings. This enabled us to answer questions such as how many farm and nonfarm jobs were associated with a particular SSN or individual in 1 year, and in which commodity or county a person had maximum earnings.

We adjusted the raw data before doing the analysis. Farm employers have reported their employees and earnings each quarter since 1978, when near-universal UI coverage was extended to agriculture. Although it is sometimes alleged that farm employers, especially FLCs, do not report all their workers or earnings, there is no evidence that underreporting of employees or earnings is more common in agriculture than in other industries that hire large numbers of seasonal workers, such as construction. We excluded from the

analysis SSNs reported by 50 or more employers in 1 year (there were 602 such SSNs and 59,776 wage records [jobs] in 2001). We also excluded wage records or jobs that had less than \$1 in earnings and jobs, or that reported earnings of more than \$75,000 in one quarter. These adjustments eliminated from the analysis 2,750 SSNs, 62,571 wage records or jobs and \$803 million in earnings. These exclusions were about 0.25%, 2.7% and 6.1% of the totals, respectively, and are documented more fully in Khan et al. (2003).

There is no single explanation for the outlier data we excluded. In some cases, several workers may share one SSN, while in others our suspicion that a SSN had "too many" jobs may represent data-entry errors.

During the 1990s, the Social Security Administration cleaned up SSNs, including threatening to fine and reject tax payments from employers with too many mismatches between SSNs and the names associated with those SSNs, which should have reduced the number of SSNs reported by employers. We think the rising number of SSNs reflects

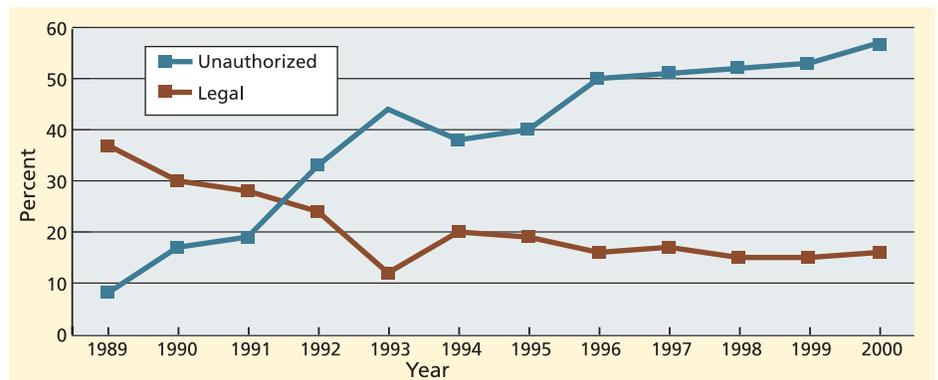


Fig. 1: Legalized and unauthorized farmworkers, 1989–2000. Source: NAWS 2001.

TABLE 2. Average agricultural employment, unique SSNs and jobs held: 1991, 1996, 2001

	1991	1996	2001
Average agricultural employment*	342,000	408,300	388,000
Unique SSNs	907,166	966,593	1,086,563
SSN/employee ratio	2.7	2.4	2.8
SSNs with one job	54%	56%	53%
Two jobs	26%	25%	26%
Three jobs	12%	12%	12%
Four jobs	5%	5%	5%
Five or more jobs	3%	2%	4%

* Monthly employment summed and divided by 12 months, drawn from EDD Current Employment Statistics (CES) program. Source: CES estimates and analysis of wage records by EDD (2003) Labor Market Information Division.

more individuals employed in agriculture, not more noise in the data.

Employees, jobs and earnings

Agricultural employment can be measured in three major ways: at a point in time, as an average over time or by counting the total number of individuals employed over some period of time. In the nonfarm labor market the three employment concepts yield similar results. If 100 workers are employed during each month and there is no worker turnover from month to month, then point in time, average and total employment is 100. However, agricultural employment during the six summer months may be 150, versus 50 during the six winter months, meaning that point, average and total employment counts differ.

We began with all SSNs reported by agricultural employers (SIC codes 01, 02 and 07), summed the jobs and earnings of these SSNs within each SIC code, and assigned each SSN to the four-digit SIC code in which the worker had the highest earnings. This means that a SSN reported by a grape employer (0172) as well as by an FLC (0176) would be considered a grape worker if his highest-earning job was in grapes.

The number of individuals or unique SSNs reported by California agricultural employers has been stable over the past decade — 907,166 in 1991, 966,593 in 1996 and 1,086,563 in 2001 (table 2). However, average agricultural employment peaked in 1996 and then fell to 388,000, suggesting that more workers shared fewer jobs in 2001. (It is possible, but not likely, that the increased number of individual

TABLE 3. Farmworkers and farm jobs: 1991, 1996, 2001

SIC	Industry title	Jobs	Employees	Earnings	Average earnings	Average earnings
					\$ millions	\$/job
1991						
01, 02, 07	Agriculture	1,540,769	907,166	8,558	5,555	9,434
01	Production (crops)	684,130	482,511	3,943	5,763	8,171
02	Production (livestock)	59,428	55,535	893	15,035	16,089
07	Services	794,948	524,344	3,711	4,669	7,078
071, 072, 076	Farm services	646,215	432,794	1,986	3,074	4,590
074, 075, 078	Nonfarm services	148,733	136,902	1,725	11,597	12,600
Subtotal	All nonag	407,449	376,480	2,585	6,344	6,866
50-59 & 70-89	Trade and services as % of all nonag jobs	57.8%	56.8%	52.0%		
Total	Ag and nonag	1,948,218	1,283,646	11,143	5,720	8,681
1996						
01, 02, 07	Agriculture	1,705,616	966,593	9,236	5,415	9,555
01	Production (crops)	694,238	498,268	4,026	5,800	8,081
02	Production (livestock)	54,496	51,368	830	15,224	16,151
07	Services	953,261	589,032	4,369	4,584	7,418
071, 072, 076	Farm services	786,422	489,633	2,428	3,088	4,960
074, 075, 078	Nonfarm services	166,839	152,422	1,941	11,634	12,734
Subtotal	All nonag	453,000	408,265	2,718	6,000	6,657
50-59 & 70-89	Trade and services as % of all nonag jobs	60.3%	58.8%	55.5%		
Total	Ag and nonag	2,158,616	1,374,858	11,954	5,538	8,695
2001						
01, 02, 07	Agriculture	1,809,503	1,086,563	11,128	6,150	10,241
01	Production (crops)	630,428	474,195	4,027	6,388	8,493
02	Production (livestock)	68,575	63,854	945	13,774	14,792
07	Services	1,107,796	721,655	6,144	5,546	8,514
071, 072, 076	Farm services	817,708	507,231	2,530	3,094	4,987
074, 075, 078	Nonfarm services	290,088	264,366	3,614	12,459	13,671
Subtotal	All nonag	697,334	609,746	4,629	6,638	7,592
50-59 & 70-89	Trade and services as % of all nonag jobs	59.7%	57.9%	55.0%		
Total	Ag and nonag	2,506,837	1,696,309	15,757	6,286	9,289

Source: Analysis of wage records by EDD (2003) Labor Market Information Division.

workers needed to produce the increased tonnage worked only outside the pay periods containing the 12th of each month in a given quarter. The 12th of the month is the pay period for which employers are asked to report employee numbers.) Farmworkers had a total of 1.5 million farm jobs in 1991, 1.7 million in 1996 and 1.8 million in 2001. One-quarter also had at least one nonfarm job — about 407,000 workers were both farm and nonfarmworkers in 1991, 453,000 in 1996 and 697,000 in 2001 (table 3).

The total California earnings of persons employed in agriculture were \$11.1 billion in 1991, \$12.0 billion in 1996 and \$15.8 billion in 2001 (all in 2001 dollars). (We converted earnings in 1991 and 1996 to 2001 earnings using the Employment Cost Index [ECI] for private industry in the western region, for wages and salaries only. We adjusted earnings using the ECI rather than the Consumer Price Index [CPI]

because the ECI measures changes in the price of labor including wages and salaries, while the CPI measures changes in the price of goods and services. Because the ECI specifically measures wage changes, the U.S. Bureau of Labor Statistics [1997] strongly recommends using the ECI when converting nominal wages to real wages.) The share of total earnings for farmworkers from agricultural employers was 77% in 1991, 77% in 1996 and 71% in 2001, indicating that in the late 1990s, farmworkers tended to increase their supplemental earnings via nonagricultural jobs.

Average earnings per job were highest in livestock, \$13,800 per job in 2001. There was little difference between average earnings per job in agricultural services (\$5,500) and crops (\$6,400). Average earnings per job were higher for the nonfarm jobs of agriculture workers (\$6,600) than for agriculture jobs (\$6,200).

TABLE 4. Earnings of primary employees (\$), 2001

Industry	SIC	Primary workers	Mean earnings	Std. dev.	Median earnings	Hours worked \$8.02/hr*	25th percentile earning	Hours worked \$6.25/hr	75th percentile earning	Hours worked \$10/hr	Total earnings
				\$			\$		\$		\$ millions
Cotton	0131	7,409	15,156	15,705	12,243	1,527	3,692	591	21,622	2,162	112
Vegs and melons	0161	55,052	11,518	13,721	8,107	1,011	3,036	486	15,226	1,523	634
Berry crops	0171	32,018	7,958	8,756	6,735	840	3,486	558	10,029	1,003	255
Grapes	0172	66,199	8,799	13,287	4,662	581	1,518	243	10,572	1,057	583
Tree nuts	0173	12,453	10,654	13,084	6,278	783	2,160	346	15,274	1,527	133
Citrus fruits	0174	5,367	11,923	13,612	7,597	947	2,665	426	17,480	1,748	64
Deciduous tree fruits	0175	23,220	6,116	8,082	3,960	494	1,530	245	7,633	763	142
Fruits and tree nuts†	0179	12,523	9,275	11,237	5,972	745	2,226	356	12,960	1,296	116
Ornamental nursery	0181	49,635	17,753	19,872	13,357	1,665	5,410	866	21,252	2,125	881
Food crops grown under cover	0182	6,109	22,764	18,227	20,504	2,557	9,491	1,519	29,465	2,947	139
General farms, primarily crop	0191	41,211	9,633	13,176	5,444	679	1,710	274	13,274	1,327	397
Beef cattle feedlots	0211	1,120	17,205	16,281	14,796	1,845	5,678	908	22,985	2,299	19
Dairy farms	0241	20,167	17,767	12,099	18,030	2,248	7,990	1,278	25,150	2,515	358
Soil prep services	0711	2,630	21,069	23,021	12,886	1,607	5,684	909	29,740	2,974	55
Crop prep svcs/market	0723	54,416	12,707	17,608	7,445	92	2,92	467	15,432	1,543	691
FLCs	0761	225,934	4,385	6,171	2,650	330	634	101	6,172	617	991
Farm manage svcs	0762	15,974	11,991	16,304	6,724	838	2,265	362	16,500	1,650	192
Lawn/garden svcs	0782	109,402	14,454	15,131	11,264	1,404	4,615	738†	18,934	1,893	1,581

* USDA-NASS (2003) reported that annual average earnings of field and livestock workers in 2001 were \$8.02 per hour; California minimum wage was \$6.25 per hour in 2001.

† Not elsewhere classified.

Source: Analysis of wage records by EDD (2003) Labor Market Information Division.

Primary farmworkers and jobs

In 2001, California's farmworkers held 2.5 million jobs, including 1.8 million jobs with agricultural employers. These agricultural jobs included 630,000 in crops, 69,000 in livestock and 1.1 million in agricultural services. The agricultural services sector includes both farm and nonfarm activities, such as veterinary and lawn and garden services; FLCs accounted for 70% of the employees reported by farm agricultural services. Fruits and nuts accounted for 53% of the crop jobs, dairy for 39% of the livestock jobs and FLCs for 58% of the agricultural services jobs. The major change between 1991 and 2001 was the drop of 54,000 jobs in crop production and increase of 313,000 jobs in agricultural services.

We placed SSNs in the detailed commodity or SIC code that reflected the maximum reported earnings for the worker, and considered workers to be primarily employed in the SIC with maximum earnings. In 2001, there were 877,000 primary farmworkers, and they included 322,000 reported by crop employers, 50,000 reported by livestock employers and 504,000 reported by agricultural service employers. Fruit and nut employers accounted for 47% of the crop-reported workers, dairy for 40% of the livestock-reported workers and

FLCs for 44% of the agricultural services-reported workers.

The major change between 1991 and 2001 was the increase in number of SSNs with their primary (highest earning) job in agriculture — from 758,000 to 877,000. There was a slight drop in the number of workers reported by crop employers, a slight increase in livestock workers and a sharp 135,000 increase in agricultural services workers, anchored by a 59,000 increase (to 226,000) in workers reported by FLCs in 2001.

Most farmworkers had only one job. In 2001, 53% of the SSNs were reported by only one employer to the EDD, 26% were reported twice, 12% three times, 5% four times and 4% five or more times. During the 1990s, about 65% of farmworkers (SSNs) were reported by one agricultural employer only, 17% to 21% by two agricultural employers, 5% by at least two agricultural employers and one nonfarm employer, and 9% to 12% by one farm and one nonfarm employer.

In the three-digit SIC codes representing more detailed commodity sectors, 60% to 83% of the employees had only one job. For example, in 2001 79% of the employees reported by dairy farms had one dairy farm job, while 7% also had a second agricultural job — 3% had a dairy job, a second farm job

and a nonfarm job, and 11% had a nonfarm job in addition to the dairy job. About two-thirds of the employees of FLCs and farm management companies had only jobs with one such employer; 22% had another farm job; 6% had an FLC job, another farm job and a nonfarm job; and 6% had a nonfarm job in addition to the FLC job.

Even more detailed four-digit SIC codes showed the same pattern: the commodities or SICs most likely to offer year-round jobs such as dairies and mushrooms (food crops grown under cover) had 70% to 80% of employees working only in that commodity, while commodities or SICs offering more seasonal jobs, such as deciduous tree fruits and FLCs, had 53% to 63% of employees working only in that commodity. At the four-digit, SIC-code level, the five largest SICs (FLCs, ornamental nursery products, crop preparation services [custom harvesters], grape employers, and vegetable and melon employers) accounted for about 45% of the agricultural wages reported.

Earnings, estimates of hours worked

Agricultural employers (SIC 01, 02 and 07) paid a total of \$11 billion in wages in 2001, an average of \$10,200 per worker (table 3). Earnings were highest for the 64,000 workers primarily employed in livestock; they aver-

aged \$14,800, followed by those primarily employed by crop employers (\$8,500) and those employed by agricultural farm services, custom harvesters and FLCs (\$5,000). There was considerable variation in earnings among workers in agricultural farm services: workers in soil preparation services (SIC 0711) averaged \$21,100 in 2001, versus \$12,700 for crop preparation services for market (custom harvesters; SIC 0723) and \$4,400 for FLC employees.

The average earnings of primarily farmworkers varied significantly, even within detailed four-digit SIC codes — in most cases, the standard deviation exceeded the mean wage (table 4). Median earnings were generally less than mean earnings, reflecting that higher-wage supervisors and farm managers pulled up the mean.

It may be possible to employ a smaller total farm workforce, with each worker employed more hours and achieving higher earnings.

If the workers in detailed commodities are ranked from lowest-to-highest paid, the lowest 25% of earners in an SIC category generally earned less than \$4,000 a year. For example, among workers primarily employed in vegetables and melons in 2001 (SIC 0161), the first quartile or 25th percentile of annual earnings was \$3,000. This reflects relatively few hours of work — if these workers earned the state's minimum wage of \$6.25 an hour in 2001, they worked 480 hours. The 25th percentile earnings cutoff was lowest for those employed primarily by FLCs, only \$634, suggesting that FLC employees receiving the minimum wage worked 101 hours. The highest 25th percentile mark was in mushrooms (food grown under cover), \$9,491, which reflects 1,519 hours at minimum wage.

The 75th percentile marks the highest earnings that a nonsupervisory worker could normally expect to achieve — 75% of workers reported earning less than this amount and 25% earned more. The 75th percentile varied widely by commodity: \$6,172 for those primarily employed by FLCs, \$10,572

for those in grapes and \$29,465 for those in mushrooms.

More labor-intensive crops, jobs

The number of individuals and jobs reported by agricultural employers increased in the 1990s, reflecting increased production of labor-intensive fruit and vegetable crops and, the data suggests, more farmworkers each worked a fewer number of hours. With the state's minimum wage at \$6.25 per hour after Jan. 1, 2001 (and \$6.75 per hour since Jan. 1, 2002), the earnings reported by employers suggest that most farmworkers are employed fewer than 1,000 hours per year (about half-time).

FLCs increased their market share in the 1990s, but dependence on them varied by commodity. For example, FLCs rather than citrus growers reported many citrus workers, while dairy employers reported most dairy workers. FLCs are associated with low earnings, which suggests few hours of work — the median earnings reported by FLCs for their employees in 2001 were \$2,650, or 400 hours if workers earned the state's

\$6.25 minimum wage.

California's farm labor market has large numbers of workers searching for seasonal jobs; FLCs are matching an increasing share of these workers with jobs, resulting in lower earnings for FLC employees. Workers who avoid FLCs experience higher earnings in agriculture or in the nonfarm labor market. If FLCs are most likely to hire recently arrived and unauthorized workers, as the National Agricultural Worker Survey (NAWS 2001) suggests, FLCs serve as a port of entry for immigrant farmworkers.

The impact of guest workers, legalization and earned legalization will depend on the details of any new program. If the status quo continues, the percentage of unauthorized workers is likely to rise. Alternatively, if there were a legalization program, farmworkers might more quickly exit the farm workforce. However, an earned legalization program could slow this exit if workers were required to continue working in agriculture to earn full legal status.

The next step in this analysis is to ex-

amine the mobility of individual farmworkers over time and geography, examining where workers migrate during 1 year and patterns of entrance to and exit from the farm workforce (Moore et al. 2002). Do farmworkers who increase their earnings by moving to nonfarm jobs stay in nonfarm jobs, or do they sometimes return to agriculture? Are geographic and economic mobility linked for workers who get nonfarm jobs? Answers to these questions will help to determine the trajectory of the farm labor market.

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Irrigation and planting density affect river red gum growth

Stephen T. Cockerham

In a 6-year study, production of river red gum, an excellent fuel-wood source, was evaluated for responses to three levels of irrigation, fertilization and planting density. Irrigation and planting density had the greatest influence on tree growth. Irrigation in the fifth and sixth years produced greater wood volume and weight per tree. Tree size was greatest in the wide spacing of the lower planting density. Fertilizer had no effect on any of the treatments. Per acre volume and weight yields were greater at the higher planting density, while individual tree height, diameter, volume and weight was greater at the low planting density. Growers seeking total wood volume per acre can increase yields with the higher density planting and irrigation.

River red gum, *Eucalyptus camaldulensis* Dehnh., has the widest natural distribution in the world of any eucalypt and has few equals as a fuel-wood source (Chippendale and Wolf 1981). Because of its high heating value, it provides significant biomass use efficiency in cogeneration and small power systems (Jenkins and Ebeing 1985). One of the fastest-growing eucalyptus species in terms of height, diameter and tree volume (King and Krugman 1980), river red gum is well adapted to the inland valleys of Southern California (Standiford et al. 1982; Moore 1983b) and has potential for commercial fuel-wood production.

Eucalypt plantations have traditionally focused on the production of firewood, charcoal and pulpwood, but with genetic improvement are increas-

ingly recognized as a resource for quality, higher value solid and reconstituted wood products. This is being driven by the sustainability of eucalyptus plantations (IUFRO 2000). Over the next 20 years, hardwood demand is expected to increase about 30% due to concerns over protection of the tropical rainforest and preference for wood products from certified sustainable forests. However, global oversupply of pulp and pulpwood in the 1990s kept eucalyptus prices low, limiting plantation establishment so that supply is not expected to keep up with the demand (Apsey and Reed 1996). Production and market opportunities for sustainable eucalyptus plantations will continue to grow for the next couple of decades.

Although the response of various eucalyptus species to nitrogen fertilizer varies (Turnbull and Pryor 1978), river red gum has been shown to respond to nitrogen fertilizer (Meskimen 1971; Crabb et al. 1983). However, because the yield response of river red gum is difficult to predict, commercial nitrogen-fertilization practices have been based on known responses of other tree crops (Moore 1983a). The management of nutrition and irrigation should improve commercial biomass yields for use of eucalyptus as an energy source (Standiford et al. 1982). Growing eucalyptus for fuel-wood could be commercially viable if intensive management to increase yield were both economical and practical.

Planting density can affect stand values because the high harvest cost of small trees produced at high densities may exceed the value of the fuel-wood produced (Hartsough and Nakamura 1990). At a density of about 650 trees per acre in a short-term harvest cycle, high yields may be possible without significantly reducing stem diameter (Moore 1983b).

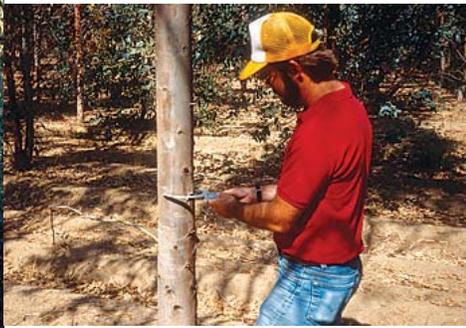
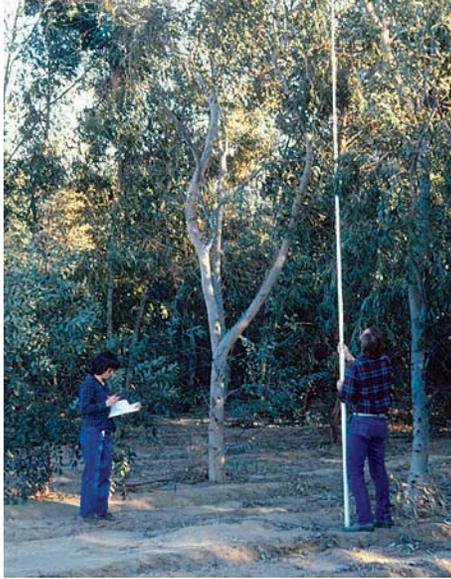


Southern California field trials

In field trials with river red gum, the variables studied were irrigation, nitrogen fertilizer and planting density. The experimental site was in a Southern California inland valley at the UC Riverside Moreno Field Station. The soil was a Ramona fine sandy loam, with a soil moisture holding capacity of 0.11 inches water per inch at 1 to 23 inches soil depth; 0.18 to 0.20 inches water at the 23 to 68 inches depth; and 0.13 to 0.15 inches water at the 68 to 74 inches depth.

Irrigation water contained 550 parts per million (ppm) total dissolved solids, with 0.77 ppm boron. (Boron is toxic to some crops at concentrations over 1.0 ppm.) Previous eucalyptus plantings at the site did not show sensitivity to boron (Moore 1983b). Annual rainfall was 24.3 inches in year 1, 8.6 inches in year 2, 7.6 inches in year 3, 6.9 inches in year 4, 10.0 inches in year 5 and 6.3 inches in year 6. The site's mean annual frost-free growing season is April 15 to Nov. 15, and it is located in *Sunset* western garden climate zone 19.

Irrigation was applied by furrow at 2.0 acre-feet per year (every 4 weeks), 4.0 acre-feet per year (every 2 weeks) and unirrigated control. Nitrogen fertilizer was applied annually as ammonium sulfate (21-0-0) shanked in 4 inches deep on one side of the tree row at 100 pounds per acre, 200 pounds per acre and unfertilized control. The plant density treatment was 302 trees per acre (spaced every 4 feet within row), 454 trees per acre (8 feet within row) and 907 trees per acre (12 feet within row), with 12 feet between all rows. The experimental design was a split plot in a split block, and the treatment design was a three factorial. Irrigation and fertilizer are the



River red gum, an Australian eucalyptus species grown for fuel wood, was tested for response to irrigation, spacing and fertilization over 6 years in Southern California. *Far left*, a furrow-irrigated research plot was planted with 12-foot spacing, and fluorescent paint was used to mark record trees. The next plot has a different spacing, and is separated by eucalyptus guard trees. *Left*, researchers used a fiberglass pole to measure tree height and, *above*, an aluminum caliper to measure diameters. *Above right*, trees were harvested to obtain the final data; guard trees were pulled before the record trees.

two main plot factors, and density as the subplot factor.

The seed source of the river red gum was the Lake Albacutya Provenance of Australia. The treatments were replicated four times. Each plot consisted of 16 trees planted four rows wide by four trees long. The center four trees were record trees used to collect data, with the surrounding 12 trees acting as guard trees. Eight-inch-tall seedlings were planted in summer 1983 and irrigated immediately, with irrigation continued to establishment. Each seedling received one-quarter to one-third ounce of a slow release 21-8-8 fertilizer in the planting hole. Treatments began a year later with the first data collection in the fall, and the experiment was terminated after 6 years. Furrow irrigation began in early April each year and fertilizer was applied in the fall.

There are different calculation methods to estimate tree wood volume. Some require measurement of the trunk diameter at several given points (Skolmen 1983; Pillsbury et al. 1989), or measurement of the height only to the 2-inch-diameter top (Metcalf 1924), which usually requires destruction of the tree. In this study, trees were measured annually in the fall for height in feet and diameter breast height (dbh) in inches at 4.5 feet above the ground. Diameter was measured with a Drescher caliper. Height was measured with a fiberglass telescoping measuring pole from the ground to the tip of the tree.

The equation used assumes each tree is a cylinder from ground level to breast height and a cone from breast height to the tip, allowing an *in vitro* estimate of whole tree volume. The

whole tree volume was calculated as $v = d^2(0.001818h + 0.1636)$ in cubic feet, where $d = \text{dbh}$ and $h = \text{height}$ (Meskimen and Franklin 1978).

At the end of the experiment the trees were cut at 6 inches above the ground. The 6 inches of tree length left in the field as stump was included in the dbh (measured as 4.0 feet from the cut end) and added to the height (length) to be included in the volume calculation, but was not added to the weight measurements. Each tree was pruned of all branches less than 2 inches in diameter and the resulting bole was weighed. The minimum size diameter for firewood is considered 2 inches (Standiford et al. 1982). A cross section approximately 1 inch thick was cut from the butt of a single tree in each treatment in one replication for moisture determination. The mean percent moisture of the green bole was determined as 47.0% with a standard deviation from the mean 3.68% (Meskimen and Franklin 1978).

Factorial analysis of variance was run to test the effects of irrigation, fertilizer, density and all interactions. For the data analysis, means were adjusted for spatial variation in the experimental plot (analysis of covariance). Means in table columns and sections with no letters in common are significantly different with Fisher's protected LSD test at $P = 0.05$. Volumes and weights were transformed to logs to homogenize variances for statistical analysis. (Means were back-transformed from means of log to the base 10 transformed volumes/weights; statistical significance was based on analysis of log-transformed volumes.)

Tree parameters after 6 years

Tree survival was high and not related to treatment effect. Fertilizer had no significant affect on any of the tree parameters measured. In addition, there were no significant interactions between irrigation, fertilizer and planting density on any of the tree parameters measured.

Height. Irrigation at 4 acre-feet increased tree height compared to the unirrigated trees (table 1). The effect of planting density on tree height was significant only in the fifth year in the high-density planting (907 trees per acre), with trees shorter in height than those at the other two spacings.

Diameter. Irrigation increased tree diameters. The trees in the highest irrigation treat-

TABLE 1. Mean tree height of river red gum ($n = 16$)

	Year 2	Year 3	Year 4	Year 5	Year 6
 feet				
Irrigation					
Unirrigated	21.1a	25.7a	33.0a	38.8ab	41.4b
2.0 ac-ft	19.5b	25.4a	32.7a	37.8b	42.6ab
4.0 ac-ft	19.9b	26.4a	34.3a	40.1a	44.1a
Significance*	s	ns	ns	s	ss
Fertilizer					
Unfertilized	20.4a	26.3a	33.4a	38.8a	42.5a
100 lb/ac	20.2a	25.7a	33.4a	39.0a	42.8a
200 lb/ac	20.0a	25.6a	33.3a	38.9a	42.7a
Significance	ns	ns	ns	ns	ns
Plant density					
302 trees	19.4a	25.8a	33.7a	39.5a	44.1a
454 trees	20.7a	26.5a	33.9a	40.1a	42.7ab
907 trees	20.0a	25.2a	32.4a	37.1b	41.3b
Significance	ns	ns	ns	sss	ss

* ns = not significant; s = significant at $P < 0.05$; ss = highly significant at $P < 0.01$; sss = very highly significant at $P < 0.001$.



Left, record trees were pushed over and pulled up with a skid steer loader, then, **center**, the trunks were cut just above the root mass for measuring. **Right**, final tree heights and diameters were measured with the tree lying on the ground.

ment (4 acre-feet per year) were significantly greater in diameter than the unirrigated trees (table 2). Diameter was most affected by tree spacing with the greatest diameter at the lowest planting density (302 trees per acre), followed respectively by smaller trunks at the closer spacings and the smallest diameters at the greatest planting density (907 trees per acre).

Whole tree volume per tree. Whole tree volume on a per-tree basis was affected beginning in year 4 due to the affect of irrigation and plant density on tree diameter (table 3). In years 5 and 6 the volume per tree in the highest irrigation treatment was significantly greater than in the unirrigated treatment. The effect of tree planting density was significant, with volume per tree increasing with the wider-spaced, lower planting density of the trees.

Whole tree volume per acre. Irrigation increased the whole tree volume per acre (table 4). In years 5 and 6 the

high irrigation rate produced more volume per acre than the unirrigated trees. Volume production at the low irrigation rate was not different from either the high irrigation rate or no irrigation. Whole tree volume per acre was significantly higher with increasing plant density as more trees, even though smaller trees, produced greater total volume.

Weight. Total weight per tree increased with irrigation, while there was no benefit from the high irrigation rate (table 5). With branches smaller than 2 inches removed, the bole weights were not significantly different among the irrigation treatments. Planting density had the greatest effect on tree weight, with the heaviest trees, whole trees and boles produced in the lowest planting density.

Density, irrigation affect growth

Planting density and irrigation had the greatest influence on tree growth. Irrigation made a difference after the

trees were well established and into the fifth and sixth years, producing larger trees, as shown by wood volume and weight per tree. Tree size was greatest in the open spacing of the lower planting density.

The planting density of 907 trees per acre yielded a mean tree size of 1.96 cubic feet and weighing 262.2 pounds green weight (139.0 pounds dry weight) per tree, while 302 trees per acre yielded a mean tree size of 4.36 cubic feet weighing 483.9 pounds green weight (256.5 pounds dry weight) per tree, an increase of 122% in size and 85% in weight.

For commercial production, the most wood was produced at the highest planting density per acre. Even though trees grown at the low planting density were bigger and heavier, they were not big enough or heavy enough to exceed the total wood volume produced per acre in the high tree population. Total per acre fuel-wood production was 1,310.5 cubic feet and 73 tons (38.7 tons

TABLE 2. Mean diameter breast height of river red gum (n = 16)

	Year 2	Year 3	Year 4	Year 5	Year 6
 inches				
Irrigation					
Unirrigated	4.1b	3.7b	4.3b	5.1b	5.8b
2.0 ac-ft	4.4a	3.8ab	4.4ab	5.3ab	6.1ab
4.0 ac-ft	4.5a	4.0a	4.6a	5.5a	6.4a
Significance*	ss	s	s	s	s
Fertilizer					
Unfertilized	4.3a	3.8a	4.4a	5.2a	6.1a
100 lb/ac	4.4a	3.8a	4.4a	5.3a	6.1a
200 lb/ac	4.3a	4.0a	4.5a	5.4a	6.1a
Significance	ns	ns	ns	ns	ns
Plant density					
302 trees	4.8a	4.3a	5.0a	6.0a	7.1a
454 trees	4.6b	4.1b	4.6b	5.5b	6.3b
907 trees	3.6c	3.2c	3.8c	4.4c	4.9c
Significance	sss	sss	sss	sss	sss

* ns = not significant; s = significant at P < 0.05; ss = highly significant at P < 0.01; sss = very highly significant.

TABLE 3. Mean whole tree volume* per tree of river red gum

	Year 2	Year 3	Year 4	Year 5	Year 6
 cubic feet				
Irrigation					
Unirrigated	0.88a	0.83a	1.33b	2.08b	2.79b
2.0 ac-ft	0.95a	0.85a	1.36b	2.16ab	3.13ab
4.0 ac-ft	1.00a	0.95a	1.60a	2.50a	3.50a
Significance†	ns	ns	s	s	s
Fertilizer					
Unfertilized	0.94a	0.87a	1.43a	2.22a	3.14a
100 lb/ac	0.96a	0.85a	1.39a	2.23a	3.05a
200 lb/ac	0.93a	0.91a	1.45a	2.27a	3.17a
Significance	ns	ns	ns	ns	ns
Plant density					
302 trees	1.19a	1.12a	1.86a	3.00a	4.50a
454 trees	1.08a	1.03a	1.57b	2.57a	3.33b
907 trees	0.65b	0.58b	0.99c	1.45b	2.03c
Significance	sss	sss	sss	sss	sss

* Volume = d²(0.001818h + 0.01636)(Meskimen and Franklin 1978).

† ns = not significant; s = significant at P < 0.05; ss = highly significant at P < 0.01; sss = very highly significant at P < 0.001.



Finally, trees were weighed with a forklift and crane scale. The authors found that river red gum trees did best when irrigated with at least 4 acre-feet of water per year and at about 900 trees per acre; fertilizer did not have an effect.

dry weight) with the widely spaced trees and up to 1,774.3 cubic feet and 118 tons (62.5 tons dry weight) in the closest spacing, an increase of 35% in volume and 63% in weight.

As potential for firewood, the smaller trees of the high-density planting retained 64% of the wood weight after removal of branches smaller than 2 inches, while the larger trees in the low-density planting retained 75%. Still, the high plant population produced, per acre, 76 tons (40.3 tons dry weight) firewood compared with 55 tons (29.2 tons dry weight) in the low density. By year 6, irrigation increased whole tree volume per tree by 25% and whole tree weight by 27%. A similar irrigation effect of 27% increase in bole weight was not statistically significant, an indication of the large sapling variability among the record trees.

Based on our study, irrigation of at least 4.0 acre-feet per year would increase fuel-wood production in planting densities of at least 907 trees per acre in commercial production of river red gum. The cost of water may be a determining factor in the use of irrigation. Nitrogen fertilizer had no effect, and is uneconomical for river red gum production in a short rotation of 6 years.

S.T. Cockerham is Superintendent of Agricultural Operations, UC Riverside. The California Department of Forestry provided partial funding for this project. The author acknowledges the contributions of Paul W. Moore, who was awarded the grant, de-

signed the experiment and established the plots; and Gregory Stapleton and William Doughty, the technicians who kept the study going.

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TABLE 4. Mean whole tree volume* per acre of river red gum

	Year 2	Year 3	Year 4	Year 5	Year 6
..... cubic feet/acre					
Irrigation					
Unirrigated	441a	412a	664b	1,035b	1,388b
2.0 ac-ft	473a	422a	678b	1,077ab	1,559ab
4.0 ac-ft	497a	475a	796a	1,244a	1,739a
Significance†	ns	ns	s	s	s
Fertilizer					
Unfertilized	470a	434a	712a	1,106a	1,567a
100 lb/ac	479a	421a	694a	1,109a	1,519a
200 lb/ac	460a	452a	724a	1,130a	1,582a
Significance	ns	ns	ns	ns	ns
Plant density					
302 trees	358c	339c	562c	904b	1,359b
454 trees	488b	463b	710b	1,163a	1,505b
907 trees	593a	527a	898a	1,317a	1,840a
Significance	sss	sss	sss	sss	sss

* Volume = $d^2(0.001818h + 0.01636)$ (Meskimen and Franklin 1978).

† ns = not significant; s = significant at $P < 0.05$; ss = highly significant at $P < 0.01$; sss = very highly significant at $P < 0.001$.

TABLE 5. Mean green weight (dry weight) per tree of river red gum after 6 years of irrigation, fertilizer and plant density treatments

	Total	Bole
..... lb/tree		
Irrigation		
Unirrigated	326.5(173.0)b	238.2(126.2)a
2.0 ac-ft	383.9(203.5)a	254.7(135.0)a
4.0 ac-ft	413.1(218.9)a	302.3(160.2)a
Significance*	sss	ns
Fertilizer		
Unfertilized	364.5(193.2)a	286.4(151.8)a
100 lb/ac	371.2(196.7)a	249.5(132.2)a
200 lb/ac	382.8(202.9)a	256.7(136.1)a
Significance	ns	ns
Plant density		
302 trees	494.9(262.3)a	366.3(194.1)a
454 trees	398.3(211.1)b	298.8(158.4)a
907 trees	262.7(139.2)c	167.6(88.8)b
Significance	sss	sss

* ns = not significant; s = significant at $P < 0.05$; ss = highly significant at $P < 0.01$; sss = very highly significant at $P < 0.001$.

Autoguidance system operated at high speed causes almost no tomato damage

Aziz Z. Abidine
Brian C. Heidman
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David J. Hills

This project explored the effectiveness of an autoguidance system based on a real-time kinematic global positioning system (RTK GPS) accurate to the centimeter (about half-inch) in agricultural production. Our objectives were to determine the effect of spacing between cultivator disks or knives and forward tractor speed on plant damage, and of deep tillage operations on drip-tape damage. Two sets of split-plot field experiments were conducted (with processing tomato transplants and direct-seeded tomatoes) in a Yolo loam field on the UC Davis campus. No significant plant damage occurred even at 7 miles per hour (mph) forward speed and cultivator disk spacing of 2 inches from the plant line. In an additional split-plot test, there was no significant damage to drip tape when the fertilizer shank was operated 2 inches from the drip tape at 3.5 mph. This system allows for automatic steering of the tractor and implements along a path close to buried drip-tape and/or plants without damaging them, even at high operational ground speeds.

The availability of global positioning systems (GPS) for civilian use has opened the possibility of locating virtually any object on the surface of the Earth to any desired degree of accuracy. Inexpensive hand-held GPS devices, costing only a few hundred dollars, can provide accuracy in the range of 10 to 66 feet and are well suited for recreational purposes such as boating. Some of these hand-held devices include

WAAS (Wide Area Augmentation System), a satellite-based free-differential correction of atmospheric and other GPS signal distortions, capable of delivering accuracy to within about 10 feet.

These systems are increasingly accepted in agriculture for scouting purposes such as locating patches of weeds or grid points. Differential GPS (DGPS) units, which use free Coast Guard beacons where available or for-fee satellite correction from vendors, can provide accuracy to less than 3.3 feet.

These systems cost about \$3,000 to \$5,000 and are widely used in precision farming for mapping yield, soil electrical conductivity and variable rate application of agricultural chemicals. At the high end of the spectrum are ultra-precise GPS units, known as real-time kinematics GPS or RTK GPS, which can provide accuracy to within about 0.4 inches on-the-go. These systems consist of a rover (a mobile unit) and a local base station; they cost \$40,000 to \$50,000.

In spite of the high cost, tractors equipped with RTK GPS are rapidly increasing in production agriculture, particularly in California, because they can successfully navigate a tractor along parallel paths with about 1 inch (2.5 centimeter [cm]) accuracy day or night. Although steering is automatic, tractors must be manned for safety and legal reasons; the automatic steering system produces an audible signal periodically to make sure that the operator has not gotten off the tractor, and the operator must turn the tractor at the headlands. Tractors equipped with these RTK GPS-based autoguidance systems enhance productivity by eliminating guess rows (beds at slightly different distances apart due to overlap while operating tractors), virtually



eliminating overlap and allowing farming to continue nearly 24 hours a day.

In addition, cultivator disks and knives can be adjusted close to plant lines (about 2 inches) and the tractor can be operated at relatively high speed (up to 7 miles per hour [mph] or more) with minimal operator input. Likewise, chemicals can be applied onto a narrow strip (3 to 4 inches) along the crop line, reducing environmental contamination and lowering costs.

Moreover, in irrigated agriculture, tractors equipped with the RTK GPS-based autoguidance system can promote the adoption of highly efficient (both in water and energy use) microirrigation systems. Drip tape can be left buried about 10 to 12 years (as opposed to replacing annually in many crop systems), and all operations can be conducted around drip tape because its location is known to within 1 inch. A typical farmer may justify switching to microirrigation if drip tapes can be used for multiple years (personal communication, Tony Turkovich, Button and Turkovich, Winters, CA). With production costs rising and competition increasing from overseas (CTRI 2001), farmers are looking for new technologies to enhance their competitiveness.



Ultraprecise global positioning systems (GPS) are now available that can guide tractors at high speeds in agricultural fields, running to within inches of plants with very little damage. Above, at UC Davis, tomato seedlings are transplanted using an autoguidance system. The GPS unit is on top of the tractor cab. Left, drip tape is installed at the same time.

Autoguidance for ag vehicles

Although interest in autoguidance dates back to the 1920s, successful systems evolved only recently (Wilson 2000; Reid et al. 2000). Early systems used mechanical sensors that sensed a crop row or furrow, followed by laser-based optical sensors (Tillett 1991). While these systems proved the feasibility of the autoguidance concept for agricultural tractors, they were not practical. The widespread availability of inexpensive and powerful microcomputers and advances in image processing led to the development of autoguidance systems based on machine vision in the 1980s and 1990s (Billingsley and Schoenfish 1997; Debain et al. 2000; Keicher and Seufert 2000; Marchant et al. 1997; Reid et al. 2000; Tillett 1991; Torii 2000; Wilson 2000).

These vision-based systems require a guidance directrix (guiding line) such as a crop row. Introduction of RTK GPS to agriculture in the past decade led to the development of a self-contained (not dependent on a crop line or furrow wall) autoguidance system. The first successful RTK GPS-based autoguidance system was demonstrated in spring 1996 (Wilson 2000). RTK GPS has increased in popularity

because of its ability to guide a tractor along the same path again and again not only within a season, but also year after year at high speeds and with minimal damage to plants, implements or drip-irrigation systems. As a result, at least three manufacturers are currently marketing autoguidance systems based on RTK GPS.

This technology may also lead to further reductions in costs for row crop production. For example, Ehsani et al. (2000) showed that planting and transplanting equipment can be instrumented to sense seeds or seedlings as they are planted and locate them precisely (to 2 inches accuracy). Such a precise plant map can subsequently target weeds using a simple greenness sensor (any green object that is not a part of the original plant map is considered a weed and can be sprayed).

Study of damage to plants, drip tape

To provide information for growers considering the adoption of an RKS GPS-based autoguidance system, we studied the effects of spacing between cultivator disks or knives and the plant line and tractor travel speed on plant damage, and the impact of deep tillage operations on damage to buried drip-tape. All field experiments were con-

ducted at the Western Center for Agricultural Equipment on the UC Davis campus. A 1,000-foot-by-250-foot section was marked off and divided into four blocks, with each block further divided into two main plots. These main plots were subjected to cultivator knife spacing of 2 or 3 inches from the plant line (main factor levels). Within each main plot, two subplots were subjected to travel speeds of either 3.5 mph or 7 mph (subfactor levels). The ground was disked, subsoil ripped, disked again and triplaned in preparation for planting.

Prior to the experiment an AB line was established using the autoguidance tractor, which served as a reference line for all subsequent field operations. An AB line is an imaginary line established by locating two points (A and B) with the autoguidance system. All crop rows are planted parallel to this line. Prior to any field operation, the tractor is driven to point A (usually located at one end of the field) and the location is marked on the RTK GPS unit; then the tractor is driven to point B (usually at the other end of the field) and marked.

Before any study operations were conducted, the implement was centered with respect to the AB line of the autoguidance system. To accomplish



Processing tomato seeds are planted using an autoguidance system. In two trials, total plant damage was 2% and zero when the autoguided cultivator was operated at 7 miles per hour and 2 inches from the plant line.

The autoguidance tractor equipped with a cultivator leaves behind a narrow strip of untilled land along the plant line.

this task, a plumb line was dropped from the tractor PTO (power-take-off shaft) and the equipment was centered directly behind the tractor PTO. To ensure that the implement followed the auto-steered tractor without influencing the tractor's steerability, sway blocks were used to obtain a clearance of about one-sixteenth inch at the hitch points. If the three-point hitch is blocked, the implement tends to steer the tractor, resulting in the loss of autoguidance accuracy.

The first operation involving autoguidance was listing to create beds in the field. A one-and-a-half-row lister (three shovels) was used to bed up the field on 60-inch beds. Subsequently, sprinklers were used to preirrigate the field. After 4 days, a single-row, early spring, 5-tine cultivating sled was used to remove any weeds. After cultivation, napropamide (a pre-emergence herbicide) was applied and a power incorporator was used to shape the beds. Once the beds were shaped, the field was transplanted, rimsulfuron (an herbicide) was applied, and the field was irrigated to establish a good stand.

Tomato transplants. After the field was properly prepared, tomato seedlings were planted using a three-row

transplanter. Drip tape with emitters located every foot was installed 5 inches away from the plant line and 5 inches below the top of the bed during the transplanting operation. A wire mesh fence was installed around the field perimeter to keep out rabbits.

Due to equipment problems, the first cultivation was delayed 33 days. The tomato plants were then approximately 1 foot tall and about 6 inches wide. A three-row cultivator was properly adjusted to obtain either 2-inch or 3-inch spacing between cultivator discs and the plant line, and tests were conducted at forward speeds of 3.5 mph or 7 mph. Following cultivation, a 30-foot section of the bed was randomly selected along each row, and plant damage was assessed by carefully looking at each plant to identify parts broken by action of the cultivator discs. Plant height was recorded for each section. A second cultivation was performed in about a week using the same procedure, and the plants were once again evaluated for damage.

Seeded tomatoes. After the transplanted processing tomatoes were evaluated for damage, the plants were chopped with a flail mower and the beds were reshaped with a power incorporator. A vacuum planter was used

to plant seeds. Unfortunately, due to high temperatures many seeds did not germinate, resulting in open space for larger and more numerous weeds.

However, we found sections of the field with a sufficient plant stand to continue the experiments. The field was cultivated 40 days after planting. Since the plants were quite small, about 6 inches high and 2.75 inches wide, a set of discs was used ahead of the cultivator knives. These discs left behind a narrow strip of untilled land along the plant line.

Once again, a strip of the bed was randomly selected along each row to evaluate plant damage due to cultivation. Since the plant stand was poor, the strip length had to be increased such that there were at least 30 plants in the strip. Following the first cultivation test, a second cultivation was conducted after 3 days and plant damage was evaluated.

Drip-tape damage. To investigate the effect of deep tillage on drip-tape damage, a fertilizer shank was pulled through the field the following spring. A split-plot design was implemented with the distance to the drip tape from the shank as the main factor and depth of the shank as the subfactor. The main factor was set at either 2 inches or 3 inches and the subfactor was either 6 inches or 8 inches. All tests were conducted at a forward speed of 3.5 mph. Following the tillage operation, the field was microirrigated to determine if the drip tape was damaged.

Damage low at high speeds

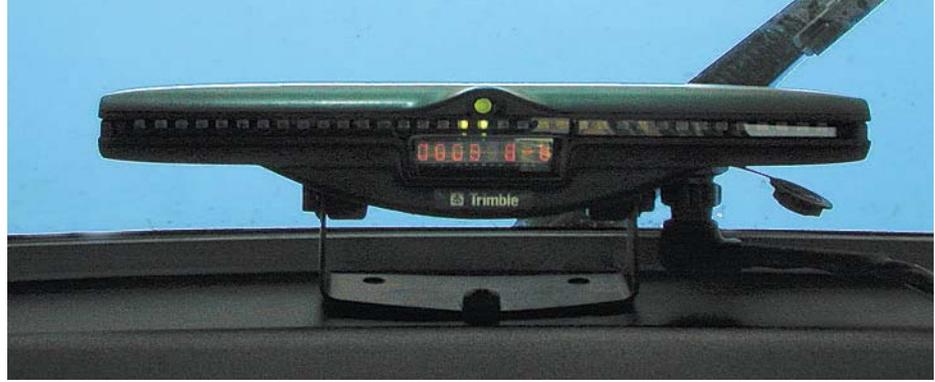
The experimental data was statistically analyzed to determine the effectiveness of the autoguidance system in enhancing the timeliness of

TABLE 1. Cultivation damage in transplanted processing-tomato trials

Trial	Speed	Spacing from plant line	
		2 in.	3 in.
	<i>mph</i> %	
First	3.5	3.3	0.0
	7.0	4.6	0.0
Second	3.5	1.1	0.0
	7.0	2.0	0.0

TABLE 2. Cultivation damage in seeded processing-tomato trials

Trial	Speed	Spacing from plant line	
		2 in.	3 in.
	<i>mph</i> %	
First	3.5	1.4	0.0
	7.0	1.7	0.0
Second	3.5	0.0	0.0
	7.0	0.0	0.0



Left, a fertilizer shank is used in deep tillage operations to determine the ability of the autoguidance tractor and implement to stay clear of buried drip-tape. *Above*, on the light bar in the tractor cab, a green LED in the center indicates that the GPS unit is on track.

the operation while minimizing plant and drip-tape damage.

Transplanted tomato damage. The data on plant damage during the cultivation was expressed as fractions. These damaged fractions were obtained by dividing the number of damaged plants in a section by the number of plants in that section. Since we used a three-row planter, there were three subsamples per observation. These subsamples were averaged before conducting the statistical analysis. The results indicated no significant differences between the low (3.5 mph) and high (7 mph) speeds (table 1). Moreover, the interaction between cultivator knife spacing and operation speed was not significant. The first cultivation with 7 mph speed and cultivator knife spacing 2 inches from the plant line resulted in about 4.6% plant damage, while plant damage was much less at all other treatments.

The main reason for increased error in the high-speed, low-spacing treatment was an error in the initial adjustment of the cultivator, which was subsequently corrected. In fact, most of the plant damage occurred in the first rows. Once the final adjustments were made, much less plant damage, if any, was observed. Moreover, the tomato plants were 6 inches high and 3 inches wide on average at the time of planting. However, by the cultivation date 33 days later, the plants had on average doubled in height and width. This larger plant volume affected plant damage negatively. (The delay in first cultivation was caused by equipment failure, as mentioned above.)

Seeded tomato damage. During the first cultivation trial, total plant dam-

age was less than 2% for the high-speed, low-spacing treatment (7 mph and 2-inch spacing from the plant line), which was more likely to cause plant damage (table 2). There was no damage at all due to any of the treatments in the second cultivation trial. These results indicate that the autoguidance system can steer a tractor very close to a plant line (within 2 inches) at relatively high speed (7 mph) without damaging plants.

Buried drip-tape. The results of the tillage study using the fertilizer shank indicate that the autoguidance system can successfully navigate a tractor close to buried drip-tape without causing damage. The experiment resulted in drip-tape damage at only one spot at the beginning of one of the 48 rows. This damage occurred because the soil was quite hard and dry, and the shank followed a prevailing crack rather than cutting the hard soil; in turn, the shank bent and cut the tape. This damage could have been avoided if the shank was more rigid or the tillage operation was conducted at a more favorable soil-moisture content. In any case, overall damage to the drip tape was negligible.

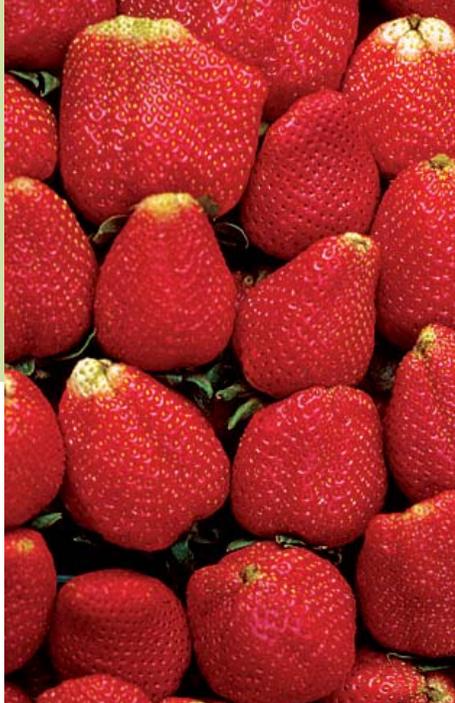
Based on the results of this study we conclude that the autoguidance tractor can successfully cultivate transplanted and seeded processing-tomato fields with minimal damage, even at a forward speed of 7 mph and a cultivator knife spacing of 2 inches from the plant line. The deep tillage operation using a fertilizer shank showed that there was no damage to drip tape when the autoguidance tractor was operated at a forward speed of 3.5 mph, 2 inches from the buried drip-tape.

A.Z. Abidine and B.C. Heidman are Graduate Research Assistants, and S.K. Upadhyaya and D.J. Hills are Professors, Biological and Agricultural Engineering Department, UC Davis. The authors are grateful to the California Energy Commission (CEC) for financial support; Trimble Navigation for equipping our JD 8700 tractor with their autopilot system; and Button and Turkovich for assisting with the experimental design and providing transplanting and cultivation equipment. We also thank Ricardo Amon of the CEC and Eric Arvesen and Bruce Stevens of Trimble Navigation for their input at various stages of this project, and Uriel Rosa, Flavio Mazetto, Eduardo Cleto and Pedro Andrade for their assistance.

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Drip irrigation evaluated in Santa Maria Valley strawberries



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Warren Bendixen

About 4,000 acres of strawberries are grown in the Santa Maria Valley using drip irrigation. In order to help growers irrigate more effectively, we conducted studies to determine crop evapotranspiration; irrigation system performance; patterns and levels of soil salinity; soil moisture content around drip lines; and irrigation water quality. We also developed canopy growth curves. Results at 13 sampling locations showed maximum canopy coverage of less than 75%. Crop evapotranspiration ranged from 12.2 inches to 15.6 inches. Irrigation-system evaluations revealed that most of the distribution uniformities were greater than 80%, considered acceptable. The electrical conductivities of the irrigation water ranged from 1 deciSiemens per meter (dS/m) to 2.36 dS/m; levels over 1 dS/m could result in yield reductions in strawberries. However, 79% of the samples had electrical conductivities equal to or less than 1.5 dS/m. Levels of soil salinity in the vicinity of drip lines ranged from 1 dS/m to 3.5 dS/m. This information can help growers calculate crop water needs and estimate irrigation set times.

About 4,000 acres of strawberries are grown in the Santa Maria Valley, a small, triangular valley about 25 miles long and 10 miles wide located along the central California coast between San Luis Obispo and Santa Barbara. Strawberries in the valley are irrigated solely by drip irrigation. As is often the case in California, the urban sector competes with agriculture for water in the valley, generating interest in reducing agricultural water use. Despite the use of drip irrigation, there is still uncertainty about the precise amount of irrigation water needed for strawberry production, including for leaching of salts and crop evapotranspiration (ET), as strawberries are sensitive to salinity and water stress.

Since 1995, we have conducted studies on drip irrigation of strawberries in the Santa Maria Valley. In order to help strawberry growers irrigate more effectively, these studies included estimating crop evapotranspiration (ET, the amount of water evaporated from plants and soil), assessing irrigation water and soil quality, evaluating drip-irrigation systems and determining patterns of salt and water around drip lines.

The Santa Maria Valley's climate is cool, with summer morning fog and moderate wind in the afternoon. The average annual rainfall is about 12 inches, most of which occurs between December and March. Little or no rainfall occurs during the summer and early fall. Soil textures consist of loamy sand and sandy loam throughout much of the valley with some clay loam near the coastline.

The sole source of irrigation water in the Santa Maria Valley is groundwater. Aquifers are recharged by percolation from the Santa Maria River and rainfall. The water quality is moderately saline

with electrical conductivities (EC) generally ranging between 1 deciSiemens per meter (dS/m) and 1.5 dS/m; its major chemical constituents are calcium, magnesium and sulfate.

Strawberry planting occurs near the end of October. Harvesting starts during the last week of February and generally continues until July. Initially, growers used 40-inch bed spacings (22-inch bed width) with one drip line and two plant rows per bed. However, during the mid-1990s many switched to 64-inch bed spacings (42-inch bed width) with two drip lines and four plant rows per bed. The advantages of wider beds include larger plant populations and higher raised beds, which aid in harvesting. Plastic mulch is used on all beds. Valleywide fresh-market yields were 31,311 pounds per acre in 1999 and 27,720 pounds per acre in 2000, while the processed strawberry yields were 27,060 pounds per acre in 1999 and 35,520 pounds per acre in 2000 (Santa Barbara County Agriculture Commissioner's Report 2000).

Glossary

DAP: days after planting

DOY: day of year

dS/m: deciSiemens per meter
(an indicator of salinity)

DU: distribution uniformity

EC: electrical conductivity

EC_e: EC of saturated soil extracts

ET_c: crop evapotranspiration

ET_o: reference crop
evapotranspiration

K_c: crop coefficient



Irrigation studies were conducted on strawberries in the Santa Maria Valley — on the Central Coast north of Santa Barbara — to help growers water their crops more efficiently. Above, strawberries here are typically planted in 64-inch beds with two drip lines and four plant rows per bed. Fertilizer is applied at the same time.

Strawberry fields in the Santa Maria Valley are normally split into drip-irrigated sections of 1 acre to 5 acres. Drip-line lengths range between 200 feet and 325 feet. High-flow, 4-mil drip tape with emitters spaced every 8 inches is installed 1 inch to 3 inches deep. Drip tapes are replaced each year.

Canopy coverage and water use

Estimating crop water and leaching requirements on farms is best done with differentially irrigated plots to develop relationships between crop yield, applied water and soil salinity. This approach was not feasible in the valley because of grower concerns about yield reductions in a crop with high cash value and high production costs. We estimated crop ET or water use by first developing relationships between canopy coverage and days after planting (DAP) at 13 locations in 1999 and 2000. We then developed a relationship between canopy coverage and crop coefficient (K_c) and then determined crop coefficients with time of year. Crop coefficients are the ratio of the actual crop evapotranspiration to a reference crop evapotranspiration (normally grass). They are used to convert the reference crop ET obtained from California Irrigation Management Information System (CIMIS) weather stations to the actual crop ET.

The relationship between canopy coverage and DAP is called a canopy growth curve. Canopy coverage is de-

finied as the percentage of soil area shaded by the plant's leaves at midday. Crop ET is directly related to canopy coverage. The canopy growth curve coupled with the relationship between canopy coverage and crop coefficient was used to develop crop coefficients during the irrigation season. To determine canopy coverage, images were made every 2 weeks with a digital infrared camera suspended 12 feet directly above the bed of the crop. The images were downloaded into a computer, and canopy coverage was calculated using software supplied by the camera manufacturer.

For canopy coverage values greater than 30%, we used the relationship between crop coefficient and canopy coverage as developed by Grattan et al. (1998); for values under 30% we used a computer model to calculate ET (Hsiao and Henderson 1985). The model's results were necessary because Grattan's relationship did not include canopy coverages less than about 30%; extrapolating Grattan's relationship for values less than 30% resulted in negative crop coefficients.

In addition, applied water and soil moisture content were measured at some of the same locations as the canopy measurements. A flow meter was installed at the beginning of each drip line to measure cumulative inflow. GroPoint dielectric soil moisture sensors were installed about 6 inches deep with two sensors at a location, one in

the plant row on each side of the drip line. Data loggers were connected to each sensor for continuous measurement of soil moisture content.

Prior to the evapotranspiration study, drip-irrigation systems were evaluated to determine their uniformity of applied water. Uniformity reflects the evenness of the applied water throughout a field and is directly related to maximum potential irrigation efficiency of a properly irrigated field, so that, for example, the least watered part of the field receives the desired amount of water needed for crop production. Measurements were taken in July, near the end of the growing season. The discharge rates of two adjacent emitters in selected fields were measured every 25 feet to 50 feet along two drip lines, one located near the manifold inlet and the other located near the end of the manifold. We calculated the distribution uniformity (DU) by averaging the low quarter of all the discharge rates and dividing by the average discharge rate.

Patterns of soil moisture content and soil salinity around drip lines were also determined at some of these earlier sites in June and July; these measurements can help growers assess the impact of irrigation management practices. Soil samples were taken at depth intervals of 3 inches for the first foot and then at 6-inch intervals. Samples were taken at five locations across the narrow beds (40-inch spacing) and at seven locations across the wide beds (64-inch spacing). Gravimetric soil moisture contents and the electrical conductivity of saturated extracts (EC_e) were obtained for the samples. Soil salinity was expressed as EC of the saturated extract. Contours of equal moisture contents and equal ECs were

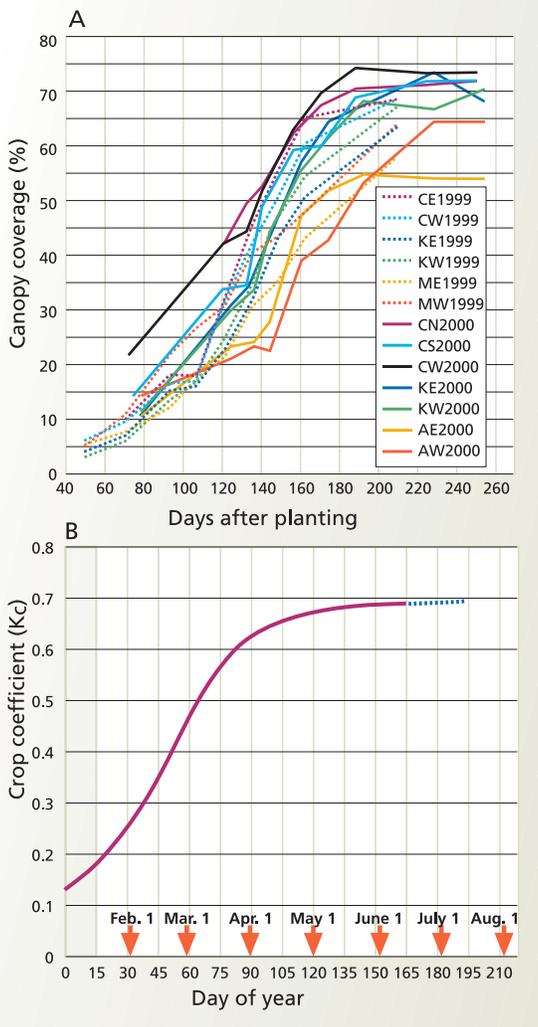


Fig. 1. (A) Canopy coverage versus days after planting at 13 locations and (B) average crop coefficients versus day of year for the Santa Maria Valley. Dotted line indicates uncertainty in data due to plant aging and damage.

drawn using SURFER (Golden Graphics, Golden, Col.). In addition, irrigation water samples were obtained at 34 locations and analyzed for EC and concentrations of soluble salts.

Canopy coverage, ET, applied water

We found considerable variability in canopy coverage among the sites (fig. 1A). The rapid canopy-growth stage generally started between 50 and 75 DAP and continued up to about 160 DAP, after which the growth rate decreased. The sites had different growth curves with maximum canopy coverages at several locations between 70% and 75%. At these locations, canopy coverage based on the bed width (about 44 inches) plus canopy

overhang was about 98% to 99%, indicating that a 70% to 75% canopy coverage based on the bed spacing (64 inches) is the maximum possible. Maximum coverages were between 60% and 75% except at AE2000 (54%), for unclear reasons. Crop coefficients expressed as a function of canopy coverage are considered more universal than those expressed on a time basis. However, growers are not likely to use crop coefficients based on canopy coverage because it is difficult and time consuming to estimate canopy coverage. Growers are more likely to use crop coefficients expressed on a time basis, such as day of year (DOY) or DAP. Therefore, we developed time-based crop coefficients using the canopy growth curves of locations with the highest maximum canopy coverages, on the assumption that maximum yields occur with maximum canopy growth. We found smaller maximum canopy coverages at some sites, but did not use them to develop crop coefficients because the impacts on yield were unknown.

The crop coefficient increased rapidly with DOY up to about the first of April (fig. 1B). Thereafter, crop coefficients increased more gradually to the maximum coefficient of about 0.69.



The authors determined crop evapotranspiration, patterns of soil salinity, soil moisture content, irrigation water quality and other irrigation variables. They also estimated canopy coverage, the percentage of soil area shaded by the plant's leaves at midday. Above, young strawberries are grown in black plastic mulch.

However, near the end of the crop season, growers experienced reduced crop ET due to plant aging, and a decrease in plant height and plant damage due to harvesting. The crop coefficient curve on figure 1B is shown as a dashed line during the late growth stage, indicating that crop coefficients may need to be decreased to reflect reduced ET.

The daily crop ET for site CN2000, for example (fig. 2), was less than 0.05 inches per day up to about 135 DAP. After 135 DAP, both crop ET and reference crop ET increased with maximum values between about 170 DAP and 230 DAP, then decreased. Maximum daily crop ET rates were about 0.14 inches per day.

The calculated season crop ET was determined from Jan. 1 to about mid-July for all locations (table 1). Seasonal ET ranged from 12.4 inches to 15.6 inches in 1999 and from 12.2 inches to 15.5 inches in 2000. As expected, locations with higher seasonal crop ET also had the highest canopy coverages. The AE2000 site, which had the smallest seasonal ET, also had the smallest maximum coverage, about 54%. It would have been useful to compare yields with seasonal ET, but yield data was unavailable.

Cumulative applied water exceeded seasonal ET_c at all 2000 sites except KE2000 and KW2000 (table 1). At these sites, the grower intentionally used

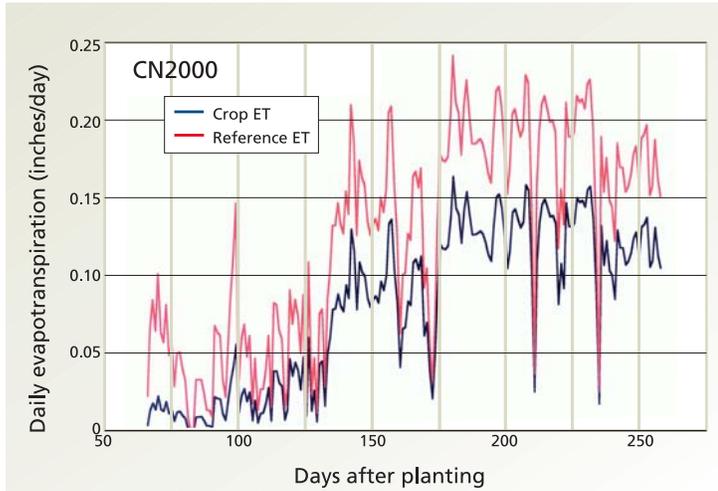


Fig. 2. Crop ET and reference crop ET for site CN2000.

deficit irrigation to reduce excessive canopy growth, which he said was a problem with his variety. Nonetheless, maximum canopy coverage was nearly 70%. Data on applied water was not available in 1999 because despite the use of filters, silt in the irrigation water caused the flow meters to malfunction, jamming the metering mechanism.

Drip system performance

With one exception, distribution uniformities (DU) of the drip-irrigation systems ranged from 81% to 96% (table 2). These high values reflect the short drip

lines, which ranged from 190 feet to 350 feet, and the new drip tape used each year. The average drip-line discharge rates ranged from 0.5 gallons per minute [gpm] per 100 feet to 0.75 gpm per 100 feet due to high-flow emitters and spacing of emitters on the drip tape. Interestingly, the drip system with the lowest DU also had the lowest drip-line discharge rate.

DU largely depends on pressure variations along drip lines and manifolds, and whether any emitters are clogged. An analysis of variance was conducted to determine the statistical significance of differences in discharge rates between adjacent emitters, and along and between drip lines. For most locations, the differences were statistically insignificant. However, at site CT2, differences between drip lines and adjacent emitters were highly significant, causing an unacceptable DU of 60%. Although we found several significant differences between drip lines and emitters among sites, they appeared to have little effect on the DUs of these systems.

Soil moisture content. Patterns of soil moisture around the drip line at one location in a sandy loam soil showed a vertical elongation of wetting under the drip tape typical in sandy soils with drip irrigation (fig. 3A). Most of the lateral wetting occurred over an interval of about 6 inches from the drip

line. Similar behavior was found at most other locations. However, at one location considerable drying occurred throughout the soil profile, particularly at depths less than about 12 inches (fig. 3B). At this site, the interval between irrigations may have been too long. This information can help growers understand how water is distributed around the drip lines and the levels of soil moisture found under drip irrigation.

Salinity. Salt in irrigation water is the main source of soil salinity, which is detrimental to salt-sensitive crops such as strawberry. Analyses of the irrigation water revealed an average EC of 1.43 dS/m (data not shown), but ranging from 1 dS/m to 2.36 dS/m. The higher values occurred at locations 3 miles to 5 miles west of the city of Santa Maria, near a waste treatment plant. However, the EC of 79% of the water samples was equal to or less than 1.5 dS/m. These waters were classified as a calcium/magnesium/sulfate water. Concentrations of calcium were slightly greater than magnesium, while sulfate dominated the anion concentrations. The relationship between total dissolved salts (TDS) in parts per million and the water EC in dS/m was:

$$\text{TDS (ppm)} = 742 \times \text{EC (dS/m)}(1)$$

The coefficient of determination was 0.97. This equation differs from that developed by the U.S. Salinity Laboratory,

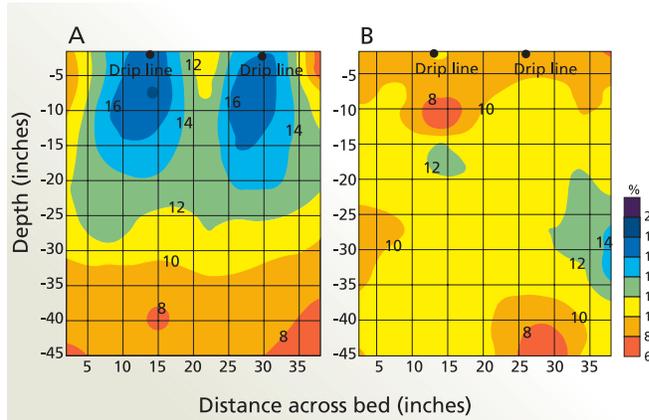


Fig. 3. Pattern of gravimetric soil moisture content (%) around the drip lines (A) just after an irrigation and (B) after several days of drying. Contour lines show equal soil moisture content. The color scale shows soil moisture content associated with colors between the contour lines.

TABLE 1. Cumulative crop evapotranspiration (ET), applied water and leaching fraction for strawberry in Santa Maria Valley, Jan. 1–July 15

Site	Crop ET	Applied water	Leaching fraction
	... inches ...		%
CE1999	15.6	*	*
CW1999	15.6	*	*
KE1999	12.9	*	*
KW1999	13.0	*	*
ME1999	12.4	*	*
MW1999	12.5	*	*
CN2000	15.5	14.5	0
CS2000	15.4	18.9	18.5
CW2000	15.5	21.6	28.2
KE2000	15.1	13.0	0
KW2000	15.1	10.4	0
AE2000	12.2	14.6	16.4
AW2000	12.8	16.1	20.5

* Data not obtained because of flow meter malfunction.

TABLE 2. Lateral length, emission uniformity and average drip-line discharge rates from nine strawberry drip-irrigation system evaluations in Santa Maria Valley

Site	Lateral length feet	Emission uniformity %	Average drip-line discharge rate gpm/100 ft
CG1	350	88	—
CT	300	80	—
CG2	287	96	0.71
GGC	190	94	0.34
BP	240	94	—
SL	300	84	0.75
RR	295	90	0.57
BSM	300	81	0.63
CT2	—	60	0.50



Levels of soil salinity around the drip lines were relatively high, indicating possible impacts on yields.

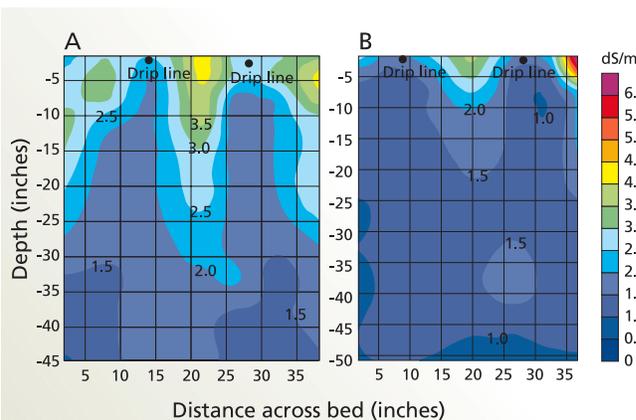


Fig. 4. Pattern of soil salinity, expressed as the EC_e (dS/m) of saturated extracts, around drip lines for sites with relatively (A) low and (B) high leaching. Contour lines show equal EC_e (dS/m). The color scale shows EC_e associated with colors between contour lines.

which used a generic constant of 640.

We found that soil salinity was least below the drip lines and decreased with depth, indicating leaching beneath the drip lines (fig. 4A, B). Maximum levels of soil salinity occurred midway between the drip lines and near the bed edges. EC_e values throughout the soil profile were smaller in figure 4B than 4A, suggesting that more leaching occurred at the figure 4B site. EC_e values for the irrigation water were similar for both sites. In general, EC_e values near the drip lines ranged from 1 dS/m to 3.5 dS/m for depths less than about 12 inches (the approximate root depth). Some EC_e values near the drip lines were similar to EC_e of the irrigation water. This reflects the high-frequency irrigation used in drip irrigation and method of determining EC_e , which involves adding distilled water to dry soil until a saturated paste forms.

At locations where soil salinity near the drip lines exceeds a threshold value, yield reductions could occur. In this case, the threshold value of about 1 dS/m is the maximum root-zone salinity that can occur in strawberries without yield reductions. Under drip irrigation, it is difficult to define the root zone around the drip line, but most of the roots are likely to occur near the drip line. Salinity measurements near the drip line provide information on the potential salinity hazard as related to crop yield.

Based on estimates of crop ET and applied water measurements, leaching fractions ranged from 0% to 28.2% for

the 2000 sites (table 1). These values reflect a fieldwide leaching fraction (leaching is the only way to control salt in the root zone). However, actual leaching fractions vary greatly with distance from drip lines. The relatively low EC_e levels found below the drip lines indicate that leaching is greater than at other horizontal distances from the drip line (fig. 4B).

Irrigation water management. Water management in drip-irrigation systems involves determining an irrigation frequency and the amount of water to apply. The irrigation frequency should be small enough to prevent excessive soil moisture depletion near the drip line, which could reduce crop yield. Intervals between irrigations were deter-

TABLE 3. Historical reference crop evapotranspiration (ET_o)*, crop coefficient (K_c) and crop ET of strawberry (ET_c) for strawberry in Santa Maria Valley

	ET_o inches/day	K_c	ET_c inches/day
Jan 1–15	0.06	0.15	0.009
Jan 16–31	0.07	0.21	0.015
Feb 1–15	0.18	0.30	0.024
Feb 16–28	0.10	0.41	0.04
Mar 1–15	0.11	0.52	0.06
Mar 16–31	0.14	0.60	0.08
Apr 1–15	0.17	0.64	0.11
Apr 16–30	0.18	0.66	0.12
May 1–15	0.19	0.68	0.13
May 16–31	0.19	0.69	0.13
Jun 1–15	0.20	0.69	0.14
Jun 16–30	0.20	0.69	0.14
Jul 1–15	0.19	0.69	0.13
Jul 16–31	0.18	0.70	0.13

* Source: Hanson and Kaita 1999.



The maximum canopy coverage for strawberries in Santa Maria Valley was 70% to 75%, with rapid growth until about 160 days after planting.

mined from the soil moisture data and ranged from 1 day to as much as 10 days. For the 2000 sites, the average interval between irrigations was 3 days to 4 days.

The amount of water applied during an irrigation should equal the crop ET between irrigations plus that needed for inefficiencies in the irrigation system. The irrigation set time, or duration of the irrigation, depends on the amount of applied water and the application rate of the irrigation system. We developed a simple equation for estimating the irrigation set time using values of historical reference crop ET (table 3) in the Santa Maria Valley (except near Guadalupe). In this equation, I is days between irrigations, q is drip-line discharge rate (gpm/100 feet), and T_s is the irrigation set time (hours). An irrigation efficiency of 85% was assumed for this calculation (based on DU data):

$$T_s = 6.52 \times ET_c \times I / q(2).$$

For example, to calculate the irrigation set time needed during the first part of June (daily $ET_c = 0.14$ inches per day) for an irrigation interval of 3 days and drip-line discharge rate of 0.6 gpm/100 feet: $T_s = 6.52 \times 0.14 \times 3 / 0.6 = 4.6$ hours.

Irrigating in Santa Maria Valley

Canopy coverage measurements made over a 2-year period revealed a maximum possible coverage between 70% and 75%, achieved at most locations. Rapid canopy growth generally occurred up to about 160 DAP. The

crop coefficient curve (fig. 1B) showed crop coefficients increasing rapidly with time to about April 1. We found a maximum coefficient of about 0.69. This time-based relationship is unique to the Santa Maria Valley, or areas with similar climates. Areas with considerably different climates may have different canopy growth curves.

An analysis of nearly 1,000 evaluations of irrigation systems (Hanson et al. 1995) found that properly designed and maintained microirrigations systems should have DUs of at least 80%, which this study showed to be feasible and practical. The drip systems used for strawberry production generally meet this minimum standard (table 2).

The effect of EC_e values found at our study locations on crop yield is unclear. Salt tolerance of some crops is greater in cool, humid climates than in hot, dry climates. Also, under the gypsiferous water and soil conditions of the Santa Maria Valley, threshold salinity values may be 1 dS/m to 3 dS/m higher than the normal threshold value at field capacity (Maas 1990). These possibilities suggest that the levels of soil salinity in the vicinity of the drip lines may not significantly affect crop yield.

In our study, applied water generally exceeded crop ET. For those locations with maximum canopy growth, the amount of applied water appears to be sufficient to meet both crop ET and leaching needed for maximum growth. However, relationships between yield and applied water are needed to determine the effect of the irrigation

management on crop yield.

The information developed in these studies allows strawberry growers to calculate crop water use between irrigations and to estimate the amount of time needed to supply the desired water. These studies also show that levels of soil salinity under drip irrigation can become relatively high, raising the possibility of crop yield reductions.

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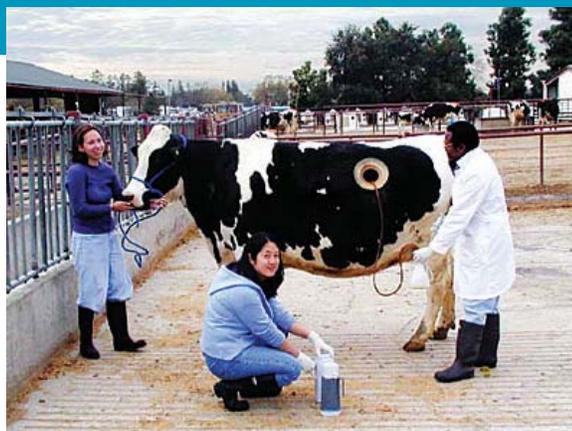
In vitro gas production provides effective method for assessing ruminant feeds

Girma Getachew
Edward J. DePeters
Peter H. Robinson

An animal's feed intake, and how well that feed is digested, determine the feed's production performance. The in vitro gas production technique is a relatively simple method for evaluating feeds, as large numbers of samples can be incubated and analyzed at the same time. This method has been applied successfully at UC Davis for a variety of purposes in feed evaluation, including calculating organic matter digestibility, the metabolizable energy of feeds and kinetics of their fermentation; determining how feed value is affected by added fat, antinutritive factors and rumen modifiers; quantifying the energy value of feed mixtures (rations); monitoring microbial change in the rumen; synchronizing nutrient digestion; and selecting forage nutrient targets for agricultural biotechnology. More than half of the nutrients consumed by ruminant animals leave the animal unutilized and undigested, and are excreted in feces, urine and gases. The in vitro gas production method can be used to examine animal waste components that impact the environment and develop appropriate mitigations.

Ruminants have a four-compartment stomach. The rumen is the largest compartment, where millions of bacteria grow under anaerobic (low-oxygen) conditions. These bacteria are responsible for the digestion of fiber (cellulose) and are the reason why ruminants

To test the digestibility of animal feeds, UC Davis graduate students Kelly McCaughey and Stefanie Cheng help postdoctoral associate Girma Getachew collect rumen fluid from "Tank." The cow has been fitted with a permanent fistula, allowing daily collection of rumen fluid.



can consume a wide variety of by-product feedstuffs derived from the processing of plants for human food. California livestock industries utilize the majority of these highly fibrous byproducts by including them in feeds for cattle, sheep and goats. The nutritive value, or energy content, of an animal feed is determined predominately by its digestibility, which affects intake, or how much the animal will eat. Digestibility and intake, in turn, determine the feed's productive performance, such as to support milk synthesis or muscle growth. However, studies with live animals (*in vivo*) to determine the digestibility of feeds are time-consuming, laborious, expensive and require large quantities of feed. Such experiments are not suited for the rapid and routine feed evaluations undertaken by commercial laboratories that provide feed information to livestock producers and feed manufacturers.

The digestibility of feeds can also be estimated by biological methods known as *in vitro* techniques, which are conducted outside of the animal system but simulate the digestion process. Generally, *in vitro* techniques are those based on measuring either fermentation residues or products. The former measures the unfermented residue remaining after *in vitro* incubation of a feed with rumen fluid. This approach involves collecting fluid by hand from the rumen of a ruminant that has been fitted with a rumen fistula (see photo

above). This method for forage evaluation was first reported in 1963, using ruminal fluid obtained from a sheep with a rumen fistula (Tilley and Terry 1963). A rumen fistula is formed by surgically transecting the skin and the rumen, suturing the rumen to the skin and allowing the rumen to heal, creating a permanent opening into the rumen. A soft cannula fits in the fistula to close the rumen. The cannula can be opened to allow access to the rumen in order to collect the bacteria-containing fluid needed for *in vitro* incubations. Material not recovered in the residue following incubation is assumed to be fermented, providing estimates of the extent of digestion for various feeds.

More recent methods measure the products of anaerobic fermentation. Rumen fermentation by anaerobic microbes results in production of short-chain fatty acids (SCFA), gases (carbon dioxide [CO₂] and methane [CH₄]) and microbial mass. The amount of gas produced is proportional to acid production, thereby serving as an indicator of acids produced by fermentation. The amount of gas produced during incubation is measured to predict the extent and rate of feed digestion.

In addition to quantifying the chemical composition of feeds, some commercial laboratories offer *in vitro* feed digestibility as a component of their feed analysis packages. This data can be used in new ration-evaluation computer models with the goal of optimiz-



Compared with laborious and expensive *in vivo* testing, the *in vitro* gas production method provides a quick and easy way to calculate organic matter digestibility, quantify the energy value of feed mixtures and monitor microbial change in the rumen. *Left*, Girma Getachew fills syringes with buffered rumen fluid.

ing nutrient utilization and animal productive performance, thereby minimizing the environmental impacts of nutrient excretion in the animal's urine and feces.

Gas-measuring techniques have been routine in feed evaluation since the early 1980s, when a high correlation was found between metabolizable energy (ME) measured in live animals and that predicted from gas production. The *in vitro* gas technique has several advantages over other *in vitro* methods that are based on measuring residues. Gas production reflects all nutrients fermented, soluble as well as insoluble; and fractions that are not fermentable do not contribute to gas production. Furthermore, the kinetics of fermentation can be obtained from a single incubation, allowing the rate of fermentation to be calculated.

Gas measurement is a direct measure of microbial activity and can be a better index of forage ME content than an indirect *in vitro* measure based on nutrients fermented. The gas technique is relatively simple and does not require sophisticated equipment, making it easy to conduct for research and commercial purposes. Rumen fluid is collected from a cow with a rumen fistula. Fermentations are conducted in large (100 milliliter [ml]) calibrated glass syringes in an anaerobic medium inoculated with rumen fluid. Incubations can be carried out either in an incubator with a rotating disc or in a thermostati-

cally controlled water bath (102°F). The volume of gas produced in 24 hours from incubating 200 milligrams (mg) of feed, together with the concentration of crude protein and crude fat, is used to predict ME. Large numbers of samples can be analyzed during a single 24-hour incubation run.

At UC Davis, three nonlactating Holstein cows (about 1,450 pounds each) are fitted with permanent rumen fistulas. Twice daily, the cows are fed a diet of mostly oat hay with a small amount of alfalfa hay. This ensures that the ruminal microbial population changes little from day to day. Rumen fluid is collected after the morning feeding using a manually operated vacuum pump. The fluid is placed into prewarmed thermos flasks, then mixed and filtered through four layers of cheesecloth and flushed with carbon dioxide in the laboratory. One part rumen fluid is mixed with two parts buffered mineral solution (1:2 volume/volume) and maintained at 102°F. Finally, this buffered rumen fluid (30 ml) is pipetted into incubation syringes containing the ground test substrate and placed in a 102°F water bath. Gas production is measured by visually reading the scale on the side of each syringe.

Applicability of gas method

The *in vitro* gas method has been applied successfully at UC Davis for a variety of purposes in feed evaluation.

Organic matter digestibility. The digestibility of measured organic matter is closely correlated with that predicted from gas production and the crude protein and ash contents of feeds. Therefore, the method can be used to predict the extent of digestion for various feeds.

Energy contents of feeds. The gas method has also been used successfully to predict the ME content of feeds. A regression equation has been developed with data generated by *in vivo* studies conducted with a variety of feeds and *in vitro* gas production. The gas measurement provides a better estimate of the ME level of feeds, when combined with some chemical constituents, compared with calculations based on chemical constituents only. Recently, seven laboratories around the world that use a gas method — including UC Davis — carried out a comparative test to assess the repeatability of the technique in predicting the energy value of feeds, and found that the gas method was repeatable among laboratories (Getachew et al. 2002).

Kinetics of fermentation. In assessing nutritive value, the rate at which a feed or its chemical constituents are digested in the rumen is as important as the extent of digestion. The pattern of feed fermentation (kinetics of fermentation) is one of several factors that influence voluntary feed intake by ruminants. The rate at which different chemical constituents are fermented is a reflec-

tion of microbial growth and accessibility of the feed to microbial enzymes. By describing gas production mathematically, kinetic data can be analyzed to evaluate substrate- and media-related differences as well as the fermentability of soluble and slowly fermentable components of feeds. The gas method is an ideal technique to generate kinetics of fermentation, as it allows recording of gas produced at several times in the incubation period, which is used to predict the rate at which feed is digested.

The gas method has been used to evaluate the effects of grain processing on the rate and extent of gas production (DePeters et al. 2003)(fig. 1). Steam-flaked corn fermented faster than whole grain. The first 16 hours of incubation were important for measuring starch availability. Different types of forages, including cereal hays and silages, were also studied to determine their patterns of fermentation in the rumen. Although alfalfa hay fermented faster during the early stages, it was lower in extent of gas production compared to corn silage after 72 hours of incubation (fig. 2).

Effects of added fat on feed degradation. Tallow and yellow grease (YG), both rendering byproducts, are typical fats used in the diets of lactating dairy cows. The gas technique was used at UC Davis to examine the effect of sources and levels of added fat on gas production and rumen fermentation of a total mixed ration (Getachew et al.



Left, dozens of syringes containing feed samples can be incubated at the same time during a single 24-hour incubation run. **Right,** gas production is measured by reading the scale on the side of the syringe.

2001)(fig. 3). Fatty acids in the form of triglyceride (YG) had no effect (when comprising up to 25% of the diet) on gas production, but fatty acids in the form of potassium salts (YG soap) significantly depressed gas production. In the animal, however, there is a limit to the amount of fatty acids that can be successfully fed, and this is lower than *in vitro*. The fatty acids in potassium salts are quickly available to microbes as free fatty acids in ruminal fluid, and have detrimental effects on microbial growth. In contrast, the fatty acids in the triglyceride form must be released through hydrolysis of the ester bond and therefore are available at a slower rate. Hydrolysis refers to breaking the chemical bond between the individual fatty acid and the glycerol backbone of the triglyceride. The effects of fatty acids on rumen fermentation are important because feeds with high levels of residual fat, for example rice bran created in the production of white rice, are commonly fed to ruminants.

Antinutritive factors. The gas method can be used to measure how microbial activity lowers feed digestibility. Some feeds, such as forage legumes and cottonseed, contain phenolics, alkaloids and saponins that have negative biological effects on microbes and reduce microbial growth in rumen. Tannins are naturally occurring polyphenolic compounds found in plants, which form complexes with feed and microbial proteins and can depress feed digestibility in the rumen. The effect of tannins on the nutritive value of feeds can be studied using tannin-binding agents, such as polyethylene glycol (PEG), which strongly binds to tannins and inhibits their biological effects. The percent increase in gas production when PEG is present indicates the rate at which tannins depress rumen fermentation of feeds.

After adding PEG to limit tannin effects, gas production increased by 22%, 71% and 211% in apple ring acacia (*Acacia albida*), beach acacia (*Acacia*

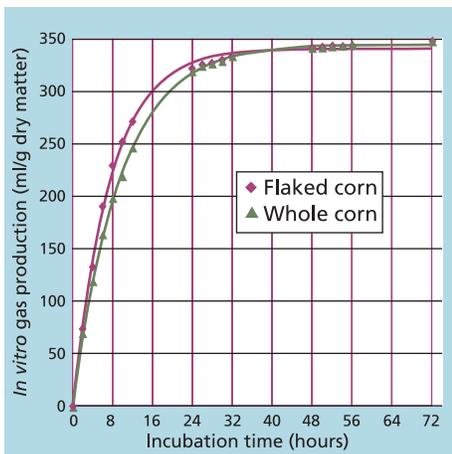


Fig. 1. Kinetics of *in vitro* gas production during incubation of flaked and whole corn grain.

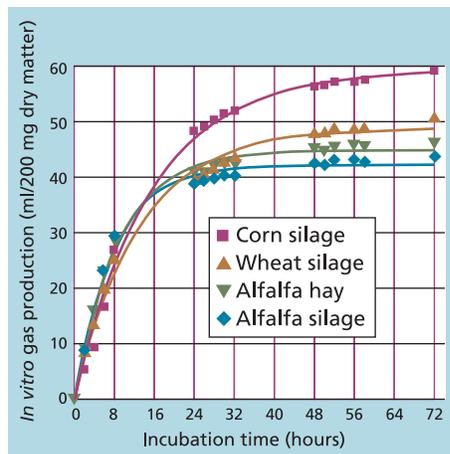


Fig. 2. Pattern of *in vitro* gas production during incubation of alfalfa hay and alfalfa, corn and wheat silages.

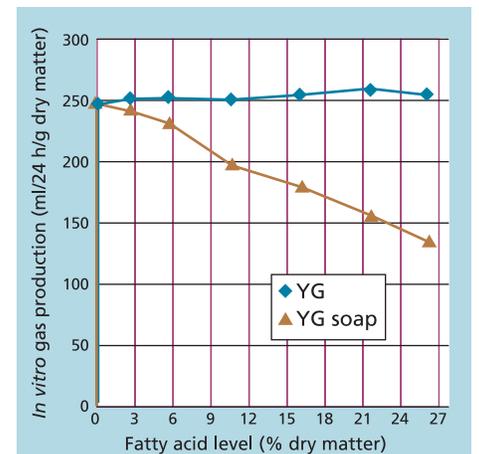


Fig. 3. Effect of yellow grease (YG) and yellow grease soap (YG soap) on *in vitro* gas production.

cyanophylla) and red calliandra (*Calliandra calothyrsus*), respectively, which are browse plants (Getachew et al. 2000b)(fig. 4).

Rumen modifiers. The gas method is also utilized to study feed additives and rumen fermentation modifiers, such as monensin sodium, by incubating feeds in the presence or absence of these compounds. Rumen modifiers are compounds that are added to the diet to modify the populations of bacteria in the rumen. For example, some compounds are fed to reduce methanogenic bacteria to reduce methane production in the rumen. Previous studies have shown that the addition of saponins and tannins in an *in vitro* system increases microbial protein synthesis (Makkar et al. 1995). Yeast and yeast fermentation products are routinely added to the diets of lactating dairy cows, although their mode of action has not been clearly identified. By studying the impact of various rumen modifiers on microbial fermentation, effects important to milk production in commercial dairy farms can be quantified.

Feed associative effects. The *in vitro* gas production method is currently being used to assess “associative” effects of feeds used in rations. Rations are mixtures of individual feeds, with a multitude of possible combinations. The energy value of a ration is generally calculated by adding up the energy values of the individual feeds in the ration, on the assumption that the individual energy value of any particular feed is the same in every possible combination with other feeds. However,



Jack Kelly Clark

More than half of the nutrients consumed by ruminant animals such as cows are undigested and excreted into the environment. By using feed evaluations to improve feed utilization, air and water pollution can be reduced.

this is not always true. For example, when poor-quality forage — such as wheat straw — is fed to a ruminant, its digestibility is low, but by adding nitrogen in the form of urea or protein, the digestibility of the straw will be increased and in turn, the energy derived from straw organic matter in the diet will be increased. Recent studies indicate that positive associative effects on *in vitro* gas production occurred when rice straw was incubated in mixtures with hay or mulberry leaves (Liu et al. 2002).

Monitoring rumen microbial change.

In addition to rates and extents of digestion, the gas production method can be used to study substrate-related factors that influence microbial popula-

tions in the rumen. This enables manipulation of rumen microflora to increase the utilization of feeds through degradation of fiber and lignin, increasing the efficiency of nitrogen utilization or allowing the degradation of anti-nutritional and toxic components of feeds. Such controlled fermentation systems could potentially be used with genetic engineering of plants to solve animal productivity problems. The technique is suitable for application of molecular-based assays, such as polymerase chain reaction (PCR) and ribonucleic acid (RNA)-targeted oligonucleotide probes, to study and measure rumen microbial growth, with the goal of increasing the efficient utilization of feeds and reducing environmental impacts. Recently, Muetzel and Becker (2003) used the gas technique, in combination with ribosomal RNA-targeted probes, to measure the efficiency of microbial growth when barley straw was supplemented with legume leaves.

Nutrient synchronization. Carbohydrate and nitrogen sources must be available simultaneously in order to maximize microbial growth. Ruminal ammonia concentrations can be influenced by the degradation rates of carbohydrates and nitrogen-containing compounds. For a given level of dietary protein, an increased rate of protein degradation enhances the ruminal am-

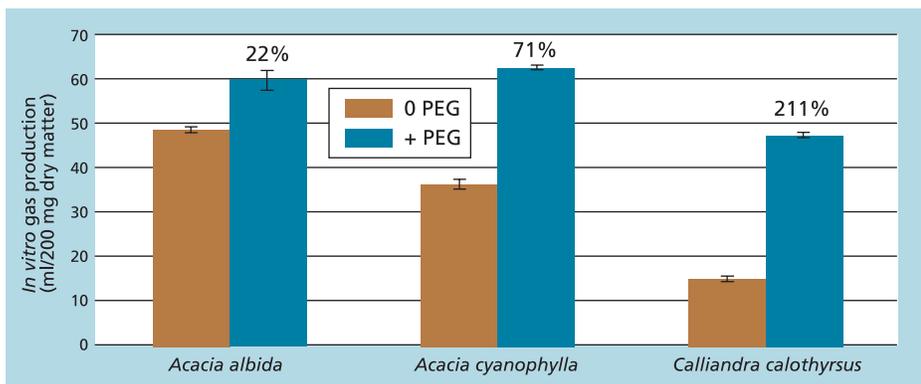


Fig. 4. *In vitro* gas production of tannin-containing leaves in absence of PEG (0 PEG, with tannins) and presence of PEG (+ PEG, with no tannins).

monia concentration while an increased rate of carbohydrate degradation decreases it. Increased carbohydrate availability for fermentation promotes microbial growth and as a result less nitrogen is lost from the rumen in the form of ammonia-nitrogen (Getachew et al. 2000a). The gas method offers an opportunity to study microbial requirements for nitrogen and carbohydrate to enable efficient fermentative activity and accumulation in the rumen. Using this technique, studies have been conducted to assess rumen microbial requirements for nitrogen when different types of carbohydrate sources are incubated.

Plant breeding, biotechnology. We believe that animal nutritionists and plant geneticists should collaborate to select genetic materials that have better agronomic performance and superior nutritional qualities. Siaw et al. (1993) used the gas technique to evaluate large numbers of browse species in order to select those high in feeding value. Browse is the edible parts of woody vegetation such as leaves, stems and twigs from bushes common on California foothills; they have been identified as integral to the development of fires that ravaged Southern California in the fall of 2003. Several forage and cereal crops have been genetically modified to increase yield, or produce chemical constituents normally deficient in a particular plant. Forage plants are selected for rapid fiber digestibility. Plants have also been genetically engineered to produce human lysozyme, but it is unclear what effect lysozyme has on microbes in the rumen. Although many genetically engineered plants are intended for human consumption, their byproducts will be fed to animals as a means of disposal. The starch contained in cereals, including corn and milo, is found in granules surrounded by a tough protein matrix that reduces enzymatic degradation. There are new genetic varieties of these cereals with modified protein matrices. We are currently using the gas production method to explore whether these new varieties increase the extent and rate of starch digestion (DePeters et al. 2003).

Environmental degradation. More than half of the nutrients consumed by ruminants leave the animal unutilized and undigested, and are excreted in feces, urine and gases. This increases animal production costs as well as environmental impacts, by contaminating surface- and groundwater and contributing to air pollution. The nitrogenous and organic compounds excreted are further decomposed and can cause odors in residential areas. Increasing the efficiency of feed utilization reduces the amount of unutilized nutrients leaving the animal. Significant reductions in nitrogenous compounds (Kuelling et al. 2003) and in methane (Johnson and Johnson 1995) can be achieved by manipulating animal diets. The *in vitro* gas method can be used to study the efficiency of feed utilization and to examine animal waste components that impact the environment in order to develop appropriate mitigation strategies.

Determining nutritive value

The nutrient composition of feeds is commonly determined primarily by chemical analyses. However, this does not provide sufficient information to determine the feed's true nutritive value. The efficiency by which an animal utilizes feed nutrients has a significant impact on its productive performance and waste production. The *in vitro* gas production system helps to better quantify nutrient utilization, and its accuracy in describing digestibility in animals has been validated in numerous experiments. Animal experiments will continue to add information to our understanding of nutrient metabolism. However, where applicable the *in vitro* gas production system can be used to predict animal performance at a much lower cost. Based on the strong relationship between measured digestibility and that predicted from gas production, regression equations have been developed and the method has been standardized.

In addition, the method can evaluate the impact of biotechnological changes in plants on their nutritive value and other factors that affect rumen fermentation.

G. Getachew is Postdoctoral Associate, E.J. DePeters is Professor, and P.H. Robinson is Cooperative Extension Specialist, Department of Animal Science, UC Davis. This research was supported by the California Agricultural Experiment Station, UC Davis.

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Tomato pomace may be a good source of vitamin E in broiler diets



Processing tomatoes, *left*, are a major California crop valued at nearly \$500 million in 2001. When tomatoes are processed into products like catsup, salsa and sauces, *right*, 10% to 30% of their weight becomes waste or "pomace."

Annie J. King
Gideon Zeidler

Dried tomato pomace, a byproduct of tomato processing, is an excellent source of α -tocopherol (vitamin E), which is used as an antioxidant in broiler meat. In a feeding study, there were no significant differences in body weight and feed per gain in chicks given diets with or without tomato pomace. Tomato pomace could be used as a source of α -tocopherol in broiler diets to decrease lipid oxidation (fat deterioration) during heating and long-term frozen storage of dark meat, and to prolong shelf life. Because tomato byproducts contain high levels of unsaturated fatty acids, the pomace must be defatted without losing vitamin E to minimize its oxidation potential. Although we found no evidence that introducing a high-fiber feed ingredient significantly limited broiler growth, more research is needed to enhance its practical applications.

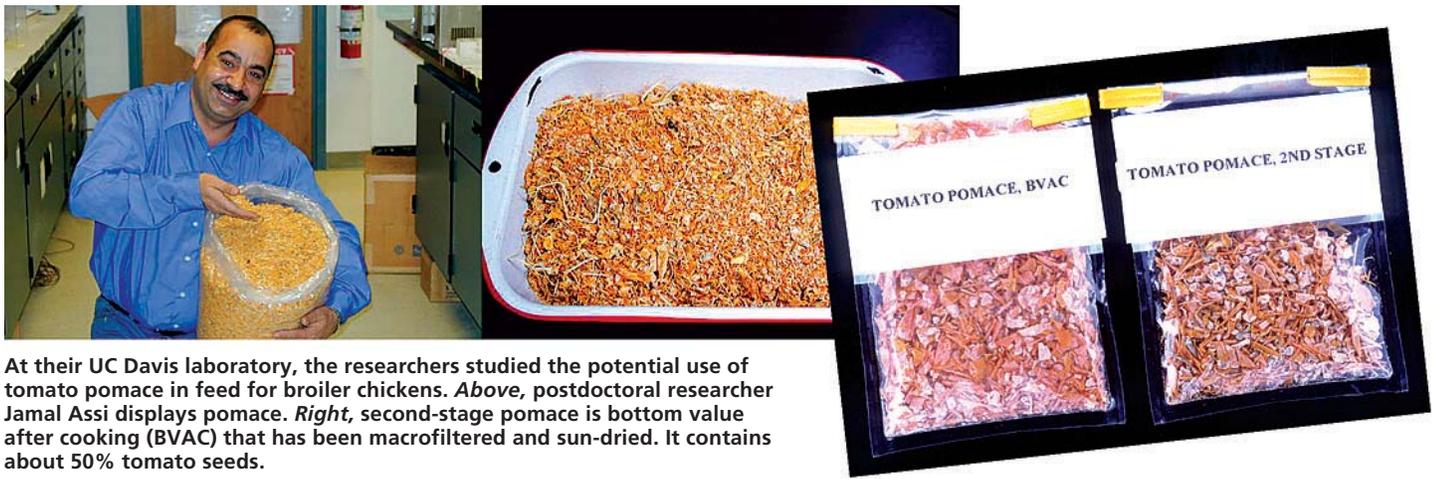
IN 2001, California farmers grew about 258,000 acres of processing tomatoes (USDA-NASS 2002), which are made into juice and concentrated products such as catsup, salsa, paste, puree, soups and sauces. About 10% to 30% of the raw tomato weight becomes waste, part of which is hauled fresh to nearby cattle and dairy farms and sold for a token fee. Tomato waste (pomace) consists of peels, cores, culls, seeds, trimmings, liquor and unprocessed green tomatoes picked by harvest machinery.

The composition of tomato pomace varies according to agricultural and processing practices, the degree of drying, moisture removal and separation of cellulose. Tomato pomace can contain up to 25% high-lysine protein and 242 parts per million (ppm) of α -tocopherol (vitamin E). Tomato pomace is recommended for cattle and dairy cow feed due to the ability of these animals to digest fiber. Likewise, tomato seeds are recommended as a source of protein isolate in food applications for humans (Kononko et al. 1986; Cantarelli et al. 1989). However, the high temperatures used to process tomatoes may affect protein extractability (Canella and Castriotta 1980).

Depending on the processing method, pomace can contain more than 31% fiber. Because high-fiber pomace (31%) is not easily digested by broilers and can dilute the available energy content of the feed, it has been used at less than 5% in the diets of these meat-type chickens. Because laying hens need less protein and are able to digest fiber, the potential use of tomato pomace in their feed is estimated as high as 15% (A. Mireles, Nutritionist/Feed Research Manager, Foster Farms, Livingston, Calif., personal communication).

The levels of α -tocopherol in tomato pomace may be particularly useful in feeds for meat animals. Tocopherols, especially the alpha (α) form, help prevent lipid oxidation (deterioration of fats). They preserve the quality of heated or stored meat by reducing the end products of oxidation that cause discoloration, off odors and off flavors. Also, some byproducts of lipid oxidation may be hazardous to human health.

Because the California broiler industry had a total value of about \$472 million in 1997 and results from this experimental animal can be obtained at an earlier age than for laying hens, young broiler chicks were used in this study. A previous study showed that



At their UC Davis laboratory, the researchers studied the potential use of tomato pomace in feed for broiler chickens. Above, postdoctoral researcher Jamal Assi displays pomace. Right, second-stage pomace is bottom value after cooking (BVAC) that has been macrofiltered and sun-dried. It contains about 50% tomato seeds.

fortification of broiler diets with 150 ppm α -tocopherol per kilogram feed for 3 to 6 weeks maintained 10 ppm of α -tocopherol in postmortem meat, enough to retard lipid oxidation by up to 50% during refrigerated and frozen storage (King et al. 1995). Other investigators have shown that vitamin C and vitamin E improved feed conversion, layer performance and the effect of heat by terminating free-radical attacks and promoting greater thyroid activity, ultimately increasing the immune response (Whitehead et al. 1998; Bollenger-Lee et al. 1999; Sahin and Kucuk 2001; Sahin, Kucuk et al. 2002; Sahin, Sahin et al. 2002). Previous research suggests that an agricultural waste product containing ample amounts of α -tocopherol could be added to feed to produce a value-added meat product.

We studied tomato pomace in chicken diets to determine if α -tocopherol in the pomace would retard lipid oxidation in stored meat, and if pomace containing about 26% fiber significantly affected bird weights at 3 weeks of age. The fiber content in our experimental diet was about 10 times greater than that used for practical feeding regimens; as such, the results provide information about the possible use of tomato pomace but cannot be applied to practical situations.

Feed formulation

We obtained pomace from four tomato varieties (Halley, Heinz 8895, Brigade and Heinz 3044) commonly grown in the Sacramento Valley. Pomace is produced from the bottom volume after cooking (BVAC), the primary end-residue from the processing line. Second-stage pomace is BVAC that is macrofiltered for large stems and leaves before sun drying. Second-stage pomace, obtained from a local tomato processing company, was transported to the laboratory within 24 hours after drying and stored at 44.6°F. Immediately after each pomace batch was received, we analyzed at least two samples for moisture, fat, protein, crude fiber, minerals, sterols, fatty acids and pesticides (carbaryl carbamates, organochlorines and organophosphates).

Results from the initial analyses of dried pomace were incorporated into a database, which was used to formulate the control and experimental diets utilizing the Mix-it computer program to determine least-cost feed formulations. To maximize any effects of tomato

pomace supplementation, a maximum amount was incorporated into test feed, resulting in unusually high fiber contents. To minimize this fiber effect, control diets were supplemented with cellulose to allow similar fiber composition across the tests. While no significant short-term effects due to high-fiber feeds have been described in the literature, such feeds are not typical in the industry due to concerns that they may restrict growth.

The control and pomace diets were formulated to meet or exceed the minimum nutrient requirements of poultry (table 1). Ground tomato pomace (224 ppm α -tocopherol) was added at 30% of the diet. Tomato pomace partially replaced soybean meal, cellulose and glucose and provided about 76 ppm vitamin E as a calculated value from components listed in table 1. The control diet contained about 29 ppm of vitamin E. Protein, fat (predominately from rendered chicken fat) and fiber were 22%, 8.0% and 7.0%, respectively, for both diets. The fatty acid content of both diets was determined at the beginning of each feeding trial.

Broiler feeding trials

For both feeding trials, 1-day-old male Arbor Acre Cross chicks were obtained from a local producer, banded and distributed randomly into groups, and placed into pens positioned in electrically heated batteries with raised wire floors. Birds were housed in a windowless room at 73.4°F and 14 hours of light per day. Feed and water were administered on demand. Weight gain was recorded twice weekly.

TABLE 1. Components of control and tomato pomace diets fed to broilers*

Tomato components	Control	Pomace
 %	
Soybean meal	47.0	29.8
Dicalcium phosphate	1.5	1.5
Calcium carbonate	1.0	1.0
Fat	5.5	3.5
Mineral mix	1.0	1.0
Tomato pomace	0	30.0
Vitamin mix	0.5	0.5
Methionine	0.3	0.3
Tryptophan	0.1	0.1
Glucose	38.5	32.1
Choline chloride	0.2	0.2
Cellulose	4.4	0.0

* Both diets met or exceeded minimum nutrient requirements of poultry. Tomato pomace consists of peels, cores, culls, seeds, trimmings, liquor and unprocessed green tomatoes.

TABLE 2. Sterol and mineral contents in tomato pomace*

Type	Amount
	<i>ppm</i>
Sterols	
Squalene	52
δ-tocopherol	913
γ-tocopherol	922
α-tocopherol	224
Brassicaster	430
Cholesterol	784
Campesterol	1,359
Stigmasterol	2,027
β-sitosterol	8,236
Minerals	
Cadmium	0.17
Calcium	148.84
Copper	0.83
Iron	6.62
Magnesium	289.75
Nickel	0.30
Phosphorous	602.10
Potassium	610.23

* Peels, cores, culls, seeds, trimmings, liquor and unprocessed green tomatoes.

The study was conducted over two consecutive summers in 1994 and 1995. During the first week of the first trial, six groups of five birds were fed the control diet. For the following 2 weeks, the control or experimental diet was fed to three groups (replications) of five birds. The entire feeding trial was repeated with eight groups of six birds following the same procedure. Thirty-nine birds each (15 from the first and 24 from the second trial) were fed the control or experimental diet.

Measuring lipid deterioration, expressible moisture. At the end of each trial, chicks were humanely slaughtered. Thigh meat was removed and pooled by treatment. It was frozen immediately in liquid nitrogen and stored at -185°F. Meat from both treatments was thawed for 1 hour at 73.4°F, then ground and analyzed immediately or after 4 days of storage (30.2°F) for thiobarbituric acid reactive substances (TBARS) — four samples for each replication (Salih et al. 1987) — as an indicator of lipid deterioration and percent expressible moisture (%EM, three samples for each replication).

Malonaldehyde, a byproduct of lipid deterioration, was extracted from meat. During heating, thiobarbituric acid was reacted with malonaldehyde to produce a solution ranging from pink to red, indicating the level of byproducts (mostly



Photos: California Poultry Federation

There was no statistical difference in weight gain between chicks fed the experimental diet with 30% pomace and a control diet. Tomato pomace contains high levels of the antioxidant α-tocopherol, which could reduce lipid deterioration and improve the shelf life of stored chicken meat. *Above*, commercial chicks and chickens feed in grow-out barns.

malonaldehyde) in the meat. The color was measured spectrophotometrically.

Analysis for %EM measured the amount of moisture expressed from meat by centrifugal force (Earl et al. 1996). The %EM was calculated as the weight of moisture expressed divided by the original weight of meat, and is related to the quality of protein in the meat. When protein in meat is damaged due to chemical processes or lipid deterioration during storage, the meat fails to retain water. In general, the higher the %EM, the lower the overall functional (protein) quality of the meat.

Statistical analysis. Mean values were determined for each item in the initial analysis. An analysis of variance was conducted on the data for weight gain, feed efficiency, fatty acid content of diets, TBARS and %EM. Duncan's new multiple range test was used to measure the significance of differences at $P < 0.05$.

Pomace in poultry diets

The tomato pomace used in this study contained 5.05% moisture, 11.93% fat, 26.88% protein and 26.30% crude fiber. The fiber content is within the range of results reported by other investigators. The content of β-carotene and selected sterols and minerals is shown in table 2.

Fatty acids contents were similar except that linolenic acid (C18:3) was statistically greater in the control diet (7.34 ppm) than in the tomato pomace diet (4.62 ppm)(table 3). Linolenic acid can increase lipid deterioration in feed and poultry meat.

Carbamate, organochlorine and or-

ganophosphate pesticides are known to be harmful to poultry and humans. These three pesticides were below detectable levels in the tomato pomace we tested.

Weight gain. Weight gain for birds fed the experimental diet (801 grams) was statistically similar to that of birds fed the control (743 grams) at $P < 0.05$. Feed conversions (weight gain divided by feed consumed [grams]) of 1.6 and 1.8 for the control and tomato pomace diets, respectively, were also similar at $P < 0.05$. Our results contrast with those of other investigators who reported that feeding 22.94% crude fiber (tomato seed meal) at 34% of the diet depressed growth by about 13% in 4-week-old chicks when compared to those consuming cotton seed meal (El Moghazy and El Boushy 1982). However, our results are similar to those of Squires et al. (1992), who showed that feeding up to 20% untreated tomato cannery waste

TABLE 3. Fatty acid content of dried ground tomato pomace* and diets

Fatty acid	Diets		
	Ground pomace	Control	Tomato pomace
	<i>ppm</i>		
C14	0.13	0.15	0.11
C16	13.10	13.31	11.94
C16:1	0.34	0	0
C18	4.61	4.65	4.43
C18:1	9.47	20.45	19.18
C18:2	58.01	58.00	55.67
C18:3	2.61	7.34	4.62
C20	0.41	NA	NA
C20:4	0.15	NA	NA
C24	0.20	NA	NA

* Peels, cores, culls, seeds, trimmings, liquor and unprocessed green tomatoes.



California Poultry Federation

had no significant effect on measured production parameters.

Although not statistically different, a detrimental effect in feed conversion of 0.20 would translate into an increase in feed consumption of 1 pound per bird at market weight and a subsequent loss of \$500,000 per year for the California broiler industry, which would be unacceptable (A. Mireles, Nutritionist/Feed Research Manager, Foster Farms, Livingston, CA, personal communication). Squires et al. (1992) suggest that alkali treatment of pomace may improve nutrient digestibility, decreasing the potential detrimental effects of supplementation.

Lipid oxidation, expressible moisture. For each storage condition, TBARS values — indicators of lipid deterioration levels — were similar for the uncooked meat of broilers fed the pomace and control diets. After 4 days of refrigerated storage, the TBARS value for meat from the control (1.23) was about 23.0% higher than from the pomace diet. This trend suggests a significant antioxidative effect for α -tocopherol from tomato pomace in meat heated before or after storage (for example, a maximum of 7 days at 39.2°F to 44.6°F or more than 2 weeks at -68°F).

Investigators have shown that byproducts from fat deterioration associate with protein to change functional properties like %EM. Our study showed that %EM was not significantly different in meat from birds fed pomace (47.27%) and the control (51.52%). This finding seems to support the results for TBARS values. Although TBARS and %EM were statistically similar for both diets, the values for diets containing tomato pomace were always numerically lower. In a preliminary study (data not shown) in which lipid oxidation was accelerated by heat and pro-oxidants, TBARS values for the meat from birds fed pomace were sig-

nificantly lower (30%) than the control. These findings indicate that some combination of tomato pomace — as a useful waste product — and α -tocopherol would be beneficial to prevent lipid oxidation in stored unheated and heated poultry meat. Ultimately, the added value of using tomato pomace for its α -tocopherol content must be assessed relative to its fiber content.

A promising vitamin E source

When tomato pomace was fed to broilers at 30% of the diet, growth was not significantly decreased. Though not significant, the decrease in feed efficiency (0.2) that is economically restrictive may be corrected with heat treatment and by lowering the available nutrient composition of tomato pomace.

Alpha-tocopherol is mainly found in tomato seeds. Microscopic analysis showed that tomato pomace contains about 50% tomato seed. If seeds were separated and fed to growing broilers in combination with pomace (not to exceed an excessive fiber level that could significantly retard growth) more α -tocopherol could be added to diets, possibly substantially reducing lipid deterioration in heated or stored poultry meat. Additional research will determine the lowest amount of pomace and seed that could be fed to achieve the desired antioxidant effect with no decrease in weight gain.

A.J. King is Food Scientist, UC Davis; and G. Zeidler is Poultry Extension Specialist, UC Riverside. Both are Professors, Department of Animal Science, UC Davis. The UC Division of Agriculture and Natural Resources Special Grants Program partially funded this research. The authors acknowledge the technical contributions of Leslie Earl, Dennis FitzPatrick, Robert Lam, Larry Jones and Steve Bates.

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Scott Bauer/USDA-ARS



While plum pox virus (PPV) has not yet reached California, this incurable tree disease threatens to spread here and affect the state's stone fruit industry. A transgenic plum variety (*Prunus domestica*), above, which is resistant to most strains of PPV, has been developed by the U.S. Department of Agriculture's Agricultural Research Service.

Special issue: Hurdles for horticultural biotechnology

Genetically engineered crops have revolutionized the landscape of American agriculture for row crops, including soybeans, corn and cotton. But this technology has had limited commercial success in horticultural crops, such as fruits and vegetables, nuts and nursery products. The first biotech crop to reach the market was the Flavr Savr tomato, and sweet corn, potato, squash and papaya varieties engineered to resist insects and viruses have been approved for commercial use and marketed. However, papaya is the only transgenic horticultural crop that has achieved a significant market share. In the next issue of *California Agriculture*, experts explore the unique technical, economic, regulatory and marketing hurdles to utilization of biotechnology in horticultural crops.

Also:

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