JULY-SEPTEMBER 2006 • VOLUME 60 NUMBER 3

California Agriculture

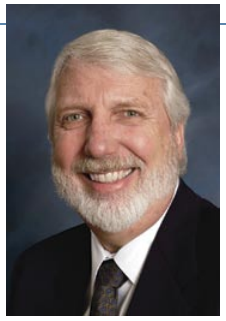
When transgenes wander, should we worry?

This issue: plants, animals and fish

University of California | Agriculture and Natural Resources | Research in Agricultural, Natural and Human Resources

Wise use of biotechnology critical to sustainable future

Paul Ludden
Dean, College of Natural Resources, UC Berkeley



Neal Van Alfen
Dean, College of Agricultural and Environmental Sciences, UC Davis

Steve Angle
Dean, College of Natural and Agricultural Sciences, UC Riverside

AS the Earth approaches its carrying capacity for human activity, we must adopt more sustainable ways to generate, distribute and consume resources. Considering the magnitude of the challenges we face, we should use all tools that can contribute to our long-term sustainability. The ability to adapt plants, animals and microbes using the traditional and new tools of biotechnology has already had an impact and will certainly play an increasing role in agriculture. Conservation of the Earth's biodiversity and its natural resources is similarly important for the future; it is our belief that the conservation of biodiversity and the judicious use of biotechnology are not mutually exclusive.

Agriculture faces many challenges including the protection of natural resources and the food supply. Just as society is concerned about the threat of emerging diseases such as avian flu and HIV to human health, we should also be concerned about the threat of diseases and pests to the sustainability of natural resources and the food supply. Those who live in California's coastal areas, and have watched the damage to oak stands by sudden oak death (SOD), can understand the vulnerability of more than just public health to emerging diseases. Scientists recently sequenced the genome for the SOD pathogen, a development that promises more rapid and conclusive diagnoses. Similarly, some scientists and growers believe that the best long-term answer to the bacterium responsible for Pierce's disease of grapevines is to develop vines that are genetically resistant to the microbe.

A number of ecological and socioeconomic crises now loom on the horizon. Global climate change may lead to changing local conditions and the need to adapt crop varieties. Changes in international and domestic farm policies, as well as world markets, pose continuing threats to many of the world's farmers.

Just as most oil production takes place abroad, ammonia-based fertilizers — a major part of the cost of agriculture — are increasingly purchased from foreign producers. Potassium and phosphorous supplies will likely be less stable in the future as well, and the production and application of all fertilizers are energy-intensive. All of these issues beg for biotechnical solutions to help farmers adapt and conserve precious resources.

Until the dawn of the industrial era, agriculture and forests provided the food, fiber and most of the energy necessary to sustain civilization. Given today's increasingly unsustainable consumption of energy resources, agriculture will once again be called upon to significantly contribute to civilization's energy needs. The world's population will likely increase by about 50% in the next 50 years, and the standard of living worldwide is increasing. These trends will result in heightened world demand for food, fiber and energy.

To meet this demand, U.S. agriculture is on the cusp of a transition equivalent to when plant breeding and synthetic fertilizers led to corn and soybeans becoming dominant crops. To meet this challenge, there will likely be a transition to genetically adapted crops with a variety of input and output traits; the new agriculture will also focus on yet-to-be-developed "energy crops" that can be used for biomass or the production of liquid fuels such as ethanol.

One of the questions that California must address is what role our agriculture will play in producing the new energy crops. Biotechnology offers appealing opportunities to develop energy crops that are markedly different from food and fiber crops. They will be drought-resistant, use nitrogen efficiently and, ideally, be harvestable during much of the year. While the cost of production in California may preclude the cultivation of crops grown more efficiently in the Midwest, biotechnology could lead to the creation of energy crops adapted specifically to regions of our state that currently struggle to be economically competitive.

Biotechnology has not yet had an impact on California's wide array of specialty crops, but research is being conducted to learn how to manipulate the genetics of these economically important crops (see *California Agriculture* 58[2]; "Fruits of biotechnology struggle to emerge"). These crops are the basis of California's competitive agricultural economy, and it is critical for UC to do the research that will keep this sector of our state's economy competitive in global markets. The potential exists to provide consumers with specialty crops enhanced by biotechnology, and managed with scientific understanding of the risks and benefits.

We are proud of the accomplishments of the faculty, staff and students at the campuses and county offices of the UC Agricultural Experiment Station and UC Cooperative Extension. Our scientists are leaders in the development and adoption of agricultural biotechnology. Ultimate decisions about how this important technology is used by our society will involve a full airing of the societal and political implications of these new crops. It is our hope that we always have faculty at the forefront of developing technology, and providing insights into its implications.

This edition of *California Agriculture* addresses a number of issues surrounding the risks and benefits of agricultural biotechnology, including transgenic plants, fish and animals (pages 116–139), and provides a glimpse of some of the important work being carried out in UC laboratories and field stations to address both.

COVER: Pollen-coated bees on a passion flower. Pollination is one of the ways that transgenic crops can hybridize with other crops and native plants. (No transgenic passion flowers have been field-tested in California) *Photo by Howard Creech.*

News departments

Biotech risks & benefits

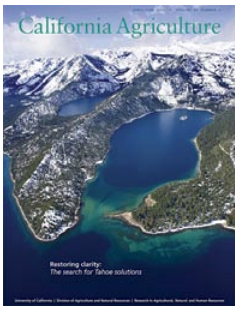
Research articles

Biotech risks & benefits

Letters

WHAT DO YOU THINK?

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



April-June 2006 issue

Assessing the health of forests

Regarding the April-June 2006 issue ("Restoring clarity: The search for Tahoe solutions"): "Nutrients flow from runoff at burned forest site in Lake Tahoe Basin" (page 65) uses the standard "unhealthy forest" examples — either composed of crowded, small trees or clogged with dead matter. Both examples are seral stages, which, if left to their own devices, would become mature forest, the crowded forest through competition and the over-littered forest through decomposition and reincorporation into new growth. Due to fire potential, humans proscribe both types; both arise mainly after logging or human-caused fires. We have scant knowledge of prehuman forest dynamics, but there are "old growth" examples where fire is not a factor for hundreds of years at a time.

The next article ("Erosion control reduces fine particles in runoff to Lake Tahoe," page 72), suggests that controlled burning has unacceptable erosion problems and mechanical clearing is expensive, terrain-limited and less suited to the individual property owner. Block isolation, fire prevention and selective harvest with attention to forest floor detail all address the "unhealthy" forest issue.

A modified mechanical mastication ("Mechanical mastication thins Lake Tahoe Forest with few adverse impacts," page 77) of fuel-loaded forests is to put all dead and thinned matter on the ground, where it decomposes most quickly to mulch and retains some moisture so as to be less flammable.

Stephen Diliberto
Graustark Agricultural Institute
Miama, Okla.

Stunned by Tahoe issue

I am stunned by the April-June 2006 issue of *California Agriculture* ("Restoring clarity: The search for Tahoe solutions"). Where is the agriculture? Lake Tahoe is a beautiful place, and there are certainly issues surrounding the mixed use of the basin, but what is the relationship of Lake Tahoe to production agriculture in California?

Last time I checked, there weren't many crops grown in the Tahoe Basin, yet 38 pages and the cover are donated to the topic. As a UC graduate, and one who has spent most of my life in production agriculture, I look to *California Agriculture* as a resource to help me increase production, lower costs, and be a better steward of a precious natural resource. Isn't there a more appropriate place to put the issues surrounding Lake Tahoe than a publication whose title suggests its emphasis is on agriculture?

Chuck Nichols
Nichols Farms, Hanford

Editor's response: California Agriculture*'s subtitle (at the bottom of the cover of each issue) is "Research in Agricultural, Natural and Human Resources." Our published manuscripts reflect these three major branches of the UC Division of Agriculture and Natural Resources. In the 60 years that the journal has been publishing, California has seen vast growth and diversification, and ANR has grown and diversified in response to the needs of the state. Today the articles in the magazine include natural resources and human resources research. However, agricultural research is still a major, and highly important, component.*

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Why do you read *California Agriculture*?

Editor's note: In the January-March 2006 issue, California Agriculture *announced a brief survey of why people read the magazine and what they would like to see covered in the future. To participate in the survey, go to http://californiaagriculture.ucop.edu, or write calag@ucop.edu. A sample of responses follows.*

I use the articles as a teaching resource in classes. The articles represent a good balance of specific data offered in a readable format. I appreciate the breadth of issues, and special issues that present a holistic approach to problem-solving. The issues are not unique to California but often represent tides of change that other regions are facing or may face in the future. A proportion of our students are from the West Coast and California, so this is an excellent way to stay informed.

I would like to see you continue with the diversity of issues as presented during the last 10 years. As a faculty member in a liberal arts college with an agriculture department, I appreciate *California Agriculture*'s width of coverage — nutrition, water issues and irrigation management, pollution, range management and pest management.

Chris Goedhart
Dordt College
Sioux Center, Iowa

As an environmental specialist for the state of Hawaii, it is beneficial to know the latest in California production and pest management research. We depend on California for most of our fresh food and are also concerned with invasive species.

I always enjoy the diversity of your articles but do find issues that crossover to Hawaii particularly useful: small-scale farming, agriculture and water-quality protection, biotechnology and invasive species.

Susan Polanco de Couet
U.S. EPA, Region 9 Pacific Islands
Honolulu, Hawaii

I have subscribed since college (a B.A. in geography from CSU Los Angeles in 1972). The main reason was to keep up with the most important industry in our state, food. I greatly enjoyed the current issue on Lake Tahoe (April-June 2006). The articles all were area-impact studies, which is what we are doing locally in Southern California, the city of Chino and the San Gabriel Mountains. The stream temperature articles were also great (July-September 2005, pages 153 to 175). I have shared information from the publication with ranchers that I know in Kern County. Please continue to keep things diverse.

Tom Leslie
Arcadia

California Agriculture begins posting articles to California Digital Library; now handling peer review online

California Agriculture is pleased to announce that we are now posting all published, peer-reviewed articles to the California Digital Library's eScholarship Repository. (PDFs will continue to be posted in full to the *California Agriculture* Web site, http://CaliforniaAgriculture.ucop.edu.)

By joining the "journals and peer-reviewed series" of the Repository, *California Agriculture* will reach a wider audience of scholars, professionals and consumers seeking scientifically sound, accessible research in the areas of agricultural, natural and human resources.

Our new site on the eScholarship Repository can be viewed at **http://repositories.cdlib.org/anrcs/californiaagriculture**. The Repository is a free, open-access database publishing the full range of scholarship. Posted materials are freely available to the public online. Since it opened in April 2002, the Repository has recorded nearly 3.4 million downloads.

With posting on the Repository, we have also established a new online system for handling manuscript submissions and managing peer review. The new system is also accessed via the *California Agriculture* eScholarship repository site. Prospective authors for *California Agriculture* can now utilize the Repository's secure server to make submissions, upload revisions and check on the status of articles. The site's simple online interface was tailored to *California Agriculture*'s needs by Berkeley Electronic Press (bepress) with its EdiKit software.

Submitting authors should visit *California Agriculture* on the eScholarship Repository at the above URL. Click on "Submit Article" and follow the instructions.

Your comments and feedback about these developments are welcome. For general comments, write calag@ucop.edu. For questions about the submission process, write Managing Editor Janet Byron at janet.byron@ucop.edu. *– Editors*

Correction: The units were incorrect in figure 3 of "Local air pollutants threaten Lake Tahoe's clarity" (April-June 2006, page 56). They should have been parts per billion (ppb) rather than micrograms per m^3. *California Agriculture* regrets the error. Corrected PDF versions may be downloaded from our Web site.

UC works to monitor, prevent, contain avian flu

Since an outbreak of virulent avian flu, H5N1, emerged in Southeast Asia in 2003, the disease has spread to wild and domestic birds on three continents. Close to 150 million birds have died or been destroyed as a result, according to the World Health Organization (WHO).

The disease spread to bird populations in Africa in February 2006, and moved into Europe at about the same time (see map). Circumstantial evidence indicates that migratory birds had introduced a low pathogenic form of avian flu into poultry flocks, where it then mutated into a highly pathogenic form, according to WHO sources.

"While there have been no documented cases of avian influenza in North American birds, there is a 90% probability that the Asian strain will eventually be introduced into California bird populations," says Scott Layne, epidemiologist at UCLA's School of Public Health.

Although human cases are extremely rare, as of June 20, 228 people in Asia, Europe and Africa had contracted the disease, and all were in close contact with infected birds. Of the humans infected 130 died, for a mortality rate of over 50%.

According to the WHO, which monitors avian flu globally, the disease is not passed from human to human at present. However, each new human case slightly increases the chance of a viral mutation leading to a form of influenza that could be passed easily from human to human.

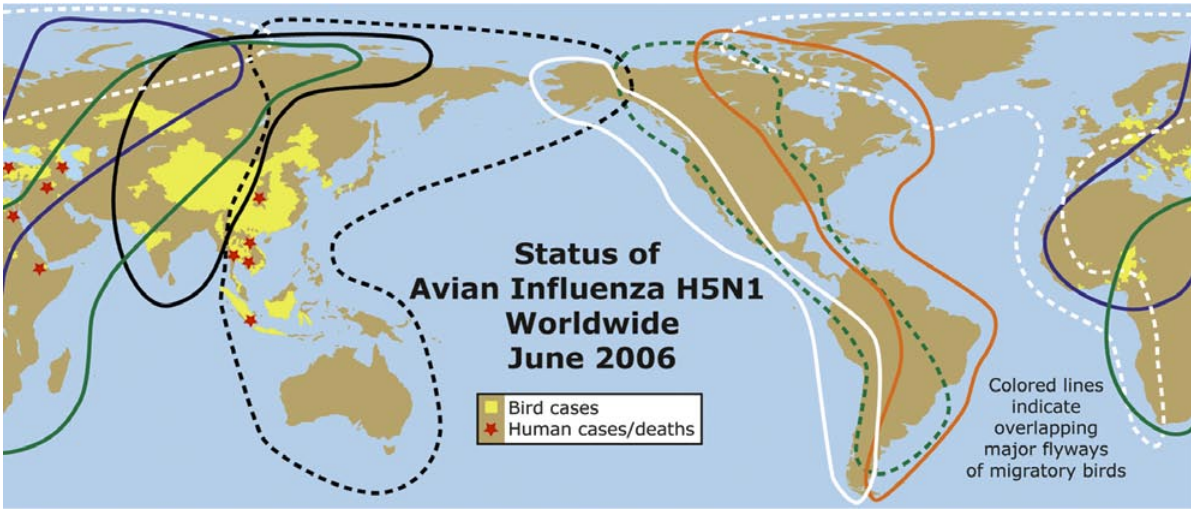
UC scientists at campuses, medical centers and Cooperative Extension offices statewide have been working to address the causes, risk factors and prevention of avian influenza in humans and birds (for a sampling of systemwide efforts, see box).

UC researchers conduct tests daily for avian influenza, which has not yet been documented in North American birds.

Detection and response

"California's front line of defense is surveillance, detection and containment, should disease be found," says Francine Bradley, UC Davis Cooperative Extension poultry specialist. While the new pathogenic strain of avian flu poses a remote hazard to Californians at present, it raises a plausible threat to California's egg and poultry industries (worth more than $1 billion in 2004), game species, wildlife, and backyard or other birds. By monitoring for the presence of diseased birds, UC experts aim to protect avian populations and reduce the virus's potential to mutate into an influenza pandemic in people.

Poultry farmers and other bird owners who find signs of illness in domestic or wild birds have a legal obligation to report it to state authorities



The current outbreak of avian flu H5N1 began in Asia in 2003 and has spread west and south, infecting people in 10 countries. Sources: avian influenza outbreaks: WHO, OIE, FAO and government sources; flyways: Wetlands International.

More avian flu research at UC

The **UCLA Center for Vaccine Research** is conducting clinical testing of a bird flu vaccine. It is one of three sites nationwide selected by the National Institute of Allergy and Infectious Diseases, part of the National Institutes of Health, to conduct such testing.

UC Cooperative Extension advisers are working with large and small poultry producers to develop detection and prevention strategies for an avian flu infection, recognizing the major economic impact the disease could have on California's poultry industry.

Lawrence Livermore National Laboratory researchers are working to develop and deploy a multiplex diagnostic for a wide range of respiratory problems, including different types of influenza; working to identify potential new signatures for multiple types of influenza viruses; and developing rapid methods for the analysis of viral genomes, including the possible mutation of avian influenza.

A team led by **UC Irvine** evolutionary biologist Robin Bush will receive $1.5 million over the next 5 years to develop computer-based simulations of pandemic flu and other infectious disease outbreaks. The research could help officials better understand how to prepare for and contain the spread of such diseases.

At **UC Davis Medical Center**, physicians are providing medical education and training for health practitioners to plan, recognize and test for cases of avian influenza in people, and putting in place procedures to deal with a possible outbreak of avian influenza.

UC San Diego Extension administers the California Office of Binational Border Health, which is working with the California Department of Health Services to address preparedness for a pandemic influenza in the California-Baja California border region.

UC faculty are working to help inform state decision-makers. When the state Assembly called a hearing recently on California's preparation for avian flu, **UCLA** associate professor Scott Layne provided expert testimony on the origins and potential threats of the disease.

The San Diego Supercomputer Center at **UC San Diego** is part of an international research effort that is using a computational data grid to study the mechanism of viral resistance to the human immune defense, provide an international data repository for different strains of avian flu, and identify new leads for drug development and screening.

— UC Editors

Sylvia Wright/UC Davis

Terra Kelly, doctoral student at UC Davis School of Veterinary Medicine, and Walter Boyce, director of the UC Davis Wildlife Health Center, explain how wild birds are tested for avian influenza.

for testing. The five laboratories of the California Animal Health and Food Safety Laboratory System monitor poultry statewide for avian influenza virus and other infectious disease organisms. Testing is conducted on flocks and individual birds every day. UC Davis School of Veterinary Medicine faculty are based at these laboratories (funded by the California Department of Food and Agriculture [CDFA]) in Davis, Turlock, Tulare, Fresno and San Bernardino. In addition, "veterinary investigators are developing new methods to sample airborne viruses and rapidly identify and respond to viral outbreaks," Bradley says.

Researchers at the UC Davis Wildlife Health Center are participating in a nationwide surveillance effort focusing on wild birds of the Pacific Flyway, testing for the presence of avian influenza infection. Sampling and virologic testing are under way in a wide variety of bird species, and duck hunters are cooperating in this effort.

Industry and producer education

With support from CDFA, Bradley and Carol Cardona of UC Davis Veterinary Medicine Extension instituted the Poultry Health Inspection Program to train inspectors at the 73 county, district and State Fair poultry shows. Experts have so far trained 148 poultry health inspectors, and they communicate regularly with fair managers.

The Game Fowl Health Assurance Program, coordinated by Bradley and CDFA veterinarian David Castellan, aims to reach a small but influential group of breeders. The program stresses biosecurity, surveillance for a variety of poultry diseases, including avian influenza, and vaccinations where appropriate. Though a small program, all poultry groups benefit, Bradley says. "We have some good sentinels in place."

Furthermore, Bradley's youth poultry program

— continued on page 112

— *continued from page 111*

trains 4-H members and other young poultry enthusiasts to keep their birds healthy. "Children don't take long to really get it," about good sanitation and protecting their birds, Bradley says.

Cardona and UC Davis veterinary professors Sharon Hietala and Tim Carpenter are also mounting a program to improve surveillance and security strategies in live bird markets that sell poultry to restaurants and consumers of traditional ethnic foods. Cardona conducts virus research at the school and also acts as a liaison with racing pigeon hobbyists and other bird owners. Clinicians at the UC Davis Veterinary Medical Teaching Hospital also work with owners of pet birds, including exotics.

Media and public outreach

Boyce, Cardona and UC Davis School of Medicine faculty members Christian Sandrock and Warner Hudson established a tightly knit team that has coordinated outreach efforts to inform the public about the many aspects of avian influenza and public-health emergency preparedness. These experts call their approach "Connection through Protection." Since September 2005, they have briefed legislators, hosted news conferences and public events, and responded to hundreds of calls from the news media.

"People can prevent flu by taking basic sanitary precautions such as hand-washing and staying home when sick," Sandrock says. "Humans must be vigilant, too, because people may be as likely as birds to introduce the virus, by unwittingly or illegally exposing healthy birds to sick animals."

The quartet is developing a "Flu School" training program that will enable others — including alumni of the UC Davis Master of Preventive Veterinary Medicine program working in 75 countries — to conduct informational workshops throughout the world. — *Lynn Narlesky and Editors*

Sylvia Wright/UC Davis

For more information

UC Office of the President
www.universityofcalifornia.edu/everyday/avianflu
www.universityofcalifornia.edu/news/2006/jan05.html

UC Davis
www.news.ucdavis.edu/special_reports/avian_flu

Veterinary Medicine Extension
www.vetmed.ucdavis.edu/vetext/INF-PO.html

UC Davis Poultry Page
http://animalscience.ucdavis.edu/Avian

California Department of Food and Agriculture
www.cdfa.ca.gov/ahfss/ah/Avian_Influenza.htm

U.S. Centers for Disease Control
www.cdc.gov/flu/avian

World Health Organization
www.who.int/csr/disease/avian_influenza/en/index.htmlx.html

Research seeks to adapt conservation tillage for California fields

AS agricultural profit margins get smaller and environmental regulations get tighter, California farmers may find relief with conservation tillage. This practice entails fewer tractor passes and so reduces the costs of fuel and labor, as well as emissions of greenhouse gases and nonpoint source pollution to air and water. Common in the Midwest, conservation tillage is relatively new to California, and UC researchers are working to adapt it to local crops and conditions.

"California agriculture is more intensive than in the Midwest, which is primarily grain crops and is thus more amenable to conservation tillage," says UC Davis soil scientist William Horwath. "Here we have many varied crops requiring specific agronomic practices. It's not a clear-cut decision, and it may not be for everyone."

Horwath is part of the Conservation Tillage Workgroup, which was established by the UC Division of Agriculture and Natural Resources in the late 1990s. Today the workgroup has nearly 500 members from UC, government agencies, farmers and environmental organizations; and more than 60 research and demonstration sites statewide. Adopted in the Midwest in the 1930s to control soil erosion, conservation tillage traditionally includes a range of practices, from no tillage at all ("no-till") to strip-till, which leaves at least 30% of the field covered with crop stubble after harvest. However, because erosion and thus crop residues are less of a concern in California, the workgroup is also evaluating practices that simply reduce tractor passes.

Reducing tractor passes

Traditional conservation tillage has considerable promise for some California agricultural operations. Tillage to prepare seed beds and control weeds typically accounts for more than one-fifth of production costs on Central Valley farms, according to Jeff Mitchell, a UC Cooperative Extension (UCCE) cropping systems specialist based at the Kearney Agricultural Center in Parlier, who also directs the Conservation Tillage Workgroup. Central Valley farms average 10 soil-preparation operations involving heavy equipment per year, and reducing the number of tillage operations can mean big decreases in both diesel use and dust production. For example, UC research has shown that conservation tillage decreases fuel use by up to 60% in back-to-back cotton crops in the San Joaquin Valley (see page 140).

Photos: Kristen Hughes/Sustainable Conservation

Ladi Asgill (right) of Sustainable Conservation and Andy Zylstra of Zylstra Dairy, which hosted conservation tillage field trials, examine Zylstra's corn crop.

***Top,* conventional tillage leaves the cornfield's soil bare and subject to significant dust production and erosion. *Bottom,* corn planted utilizing conservation tillage produces significantly less dust, because wheat residue left in the field protects the soil from blowing away. Both photos were taken on the same day at Zylstra Dairy in Turlock, Calif.**

In addition, UC research has shown that certain conservation tillage approaches can decrease dust production by about 60% or more, according to Mitchell. The San Joaquin Valley has some of the worst air quality in the country, especially for airborne particles; those that are 10 microns or less (PM-10) can cause severe respiratory problems. About 40% of the valley's PM-10 comes from agriculture, and about half of that (80 tons per day) from soil preparation alone.

Conservation tillage may be particularly effective for Central Valley dairy producers, according to a recent pilot project sponsored by UCCE and Sustainable Conservation, a nonprofit environmental organization that works with industry, agriculture and government agencies. "The project showed that conservation tillage reduced dairy producers' costs by $28 per acre and reduced dust by up to 80%," says Kristen Hughes, the dairies project manager for Sustainable Conservation. Moreover, while dairy forage is typically double-cropped, conservation tillage also allowed for triple cropping.

Besides saving money on feed costs, triple cropping lets dairy producers use more cow manure on fields, thereby reducing water quality impacts. For example, planting an extra corn crop increased nitrogen uptake by crop plants by 125 pounds per acre. The combination of conservation tillage and triple cropping could let dairy producers apply more manure and still meet new nutrient-runoff restrictions proposed by the Central Valley Regional Water Quality Control Board. "The Board is proposing new regulations saying farmers can't apply more manure nutrients than the crops need," Hughes says. "This will keep excess nutrients and salt out of the water."

Mixed results

Other pilot studies on conservation tillage in California have yielded mixed results, such as a UC project to see if the practice reduces runoff. "Conservation tillage works for heavy residue crops like corn," says Horwath. "Not so for tomatoes, which are low residue." While leaving crop stubble reduces winter water-runoff from corn by up to 40%, it can actually increase winter runoff from tomatoes by 20%. However, the study also showed that this increased runoff could be mitigated by growing winter cover crops, which both protect soil from raindrops and make it easier for water to infiltrate soil.

Similarly, cover cropping was also critical in another UC study, which found that conservation tillage increased soil salt levels in a San Joaquin Valley cotton-tomato rotation (see page 146). Again, the study also showed that this salt buildup could be mitigated by growing a winter cover crop.

While promising, traditional conservation tillage may not work for all of California's crops and agricultural conditions. Mitchell suggests that conservation tillage may apply to dairy forage and bioenergy crops, while reduced-pass or "minimum till" may apply to higher-value vegetable crops. However, Mitchell says "many questions remain to be answered and there are innovative systems being evaluated and developed with each new season."

— *Robin Meadows*

Editor's note:

Examining biotechnology's risks and benefits

The power of genetic manipulation first became apparent in the mid-1800s, when Gregor Mendel established the rules of inheritance through painstaking experiments with garden peas. Soon after, California's Luther Burbank extended his findings by breeding more than 800 varieties of fruits, flowers, vegetables, grains and grasses. The new understanding of genetics, combined with landmark discoveries at the molecular level, laid the groundwork for genetic engineering. In the Outlook at right, Peggy Lemaux takes stock of the current prospects for this technology in California agriculture.

In the peer-reviewed articles that follow (pages 116 to 139), California Agriculture *launches a special series on the risks and benefits of biotechnology in agriculture: "When transgenes wander, should we worry?"*

We previously covered the obstacles facing horticultural biotechnology ("Fruits of biotechnology struggle to emerge," April-June 2004) and biotechnology's promise ("On the horizon: Agriculture's new millennium," July-August 2000). In our judgment, the risk-benefit picture for biotechnology merits equally careful attention in this special series.

Authors in the current issue consider transgenes in crop plants, fish and animals; future articles will examine genetically modified insects, pharmaceutical plants and rice. Your thoughts and comments on this series are welcome; please write to calag@ucop.edu.

Susan Webster

UC Davis graduate student Lisa Malm plates tomato seeds in order to see if genetic traits were successfully transferred to a plant.

Outlook

Timeline uncertain for agricultural biotechnology

by Peggy G. Lemaux
Cooperative Extension Specialist, UC Berkeley

With the identification of deoxyribonucleic acid (DNA) as the basis for genetic inheritance in 1953, and the recognition that its simple chemical language of nucleotides — A's, C's, G's and T's — was responsible for life's abundant forms, scientists began unraveling the mysteries of genetic inheritance. This discovery formed the basis for the development of recombinant DNA (rDNA) methods, first reported in 1973 by California scientists Stanley Cohen and Herbert Boyer. They demonstrated that it was possible to move functional segments of DNA from one organism to an unrelated organism — a technique commonly called genetic engineering or biotechnology.

The first use of genetic engineering to modify plants was reported in tobacco in 1983, and the first commercial genetically engineered plant, the FlavrSavr tomato, was marketed in 1994 by a California company, Calgene (*California Agriculture* 54[4]:6-7). Although the tomato was later taken off the market, other commercialized crops have entered — most notably large-acreage crops such as canola, corn, cotton, soy and most recently alfalfa. A few minor-acreage crops have met with limited commercial success: papaya, certain types of squash and sweet corn.

However, if success were measured by the increase in global acreage of these crops, certainly genetically engineered crops have been successful; in 2005, the billionth acre was planted. About 8.5 million farmers in 21 countries have carried out the planting, although most of the acreage was in the United States, with almost none in Europe (James 2005). Acceptance by consumers has not come so easily, and the majority are still not aware that they are eating genetically engineered foods (Pew Initiative on Food and Biotechnology 2006; James 2004).

Despite the acreage devoted to genetically engineered crops, the diversity of crops and traits is limited. Nearly all commercial, genetically engineered crops are either those which carry pest-killing genes from the bacterium *Bacillus thuringiensis* (Bt), or those carrying herbicide tolerance, pre-

Photos: Seed Biotechnology Center

Above and right, **Allen Van Deynze, professional researcher with the UC Davis Seed Biotechnology Center, collects leaf tissue in order to extract DNA for the detection of induced modifications in tomato.**

dominantly to Monsanto's glyphosate (Roundup) herbicide. In addition, with the exception of genetically engineered papaya, which was developed by public-sector scientists, all commercial varieties on the market in 2006 came from the private sector (*California Agriculture* 58[2]).

The insecticidal and herbicide-tolerant traits are focused on improving the lot of the farmer. But, if used responsibly, some scientists believe that these improvements can also be beneficial to the environment. This has been most dramatically demonstrated by the decreases in insecticide application since the cultivation of Bt cotton (Sankula et al. 2005; Benbrook 2004). Estimates of whether herbicide use has increased or decreased vary depending on the crop, location and calculation method used, but the types of herbicides being used and the ease of use has resulted in a shift to more environmentally friendly herbicides (Fernando-Cornejo and McBride 2002).

A look down the pipeline for future applications of biotechnology for agricultural crops is clouded by a number of factors. Although public-sector scientists have played a role in variety development, their ability to do so in the arena of genetically engineered crops is limited by issues such as regulatory costs and inadequate access to key technologies due to intellectual-property protections (patented technologies and genes). These factors, as well as consumer acceptance, will determine whether genetic technologies will be used to address problems specific to the small-acreage crops important to California.

Responding to the impact of these obstacles, crop biotechnology is adding a new chapter. A UC-based initiative called Public Intellectual Property for Research in Agriculture (PIPRA) is creating a public-sector "toolbox" through an intellectual-property consortium that is focused on identifying enabling technologies that will overcome some of the existing constraints (Graff et al. 2004). Also, the national group Specialty Crops Regulatory Initiative (SCRI), with strong California representation, is leading an effort to ease small-market and specialty genetically-engineered crops through the costly regulatory-approval processes. With these factors playing a role, perhaps the promise of biotechnology for California's small-acreage crops will be realized.

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For more information:

PIPRA: www.pipra.org

SCRI: www.csrees.usda.gov/nea/biotech/part/biotechnology_part_specialty.html

UC Statewide Biotechnology Workgroup:

http://ucbiotech.org

REVIEW ARTICLE

When crop transgenes wander in California, should we worry?

by Norman C. Ellstrand

The movement of transgenes into populations for which they are not intended remains a primary concern for genetically engineered crops. Such gene flow in itself is not a risk. However, we know that the transfer of genes from traditionally improved crops into wild populations has already resulted, on occasion, in the evolution of weeds more difficult to control, as well as an increased extinction risk for rare species. Just like traditional crops, genetically engineered crops could occasionally create the same problems. Currently in California, the movement of transgenes from most commercialized transgenic crops into wild plant populations is unlikely — the exception being canola. However, other transgenic plants have been field-tested in California, and if these become commercialized, in certain cases, transgenes are likely to move into the wild or into other crops of the same species. Such gene flow could result in various problems. The best containment for transgenes may involve risk assessment decisions by scientists embarking on projects to determine whether the proposed combination of organism and trait will pose any problems and if so, to determine how to create a safe product.

Jack Kelly Clark, UC Davis

wildscaping.com

Jeff Abbas, 2001

Scientists are studying the implications of gene flow between cultivated crops and their wild relatives, a common phenomenon between plant species. For example, studies have considered, *top left,* cultivated wine grape (*Vitis vinifera*) and its wild relative, *top right,* California wild grape (*Vitis californica*), as well as, *bottom left,* crop radish and, *bottom right,* wild radish (*Raphanus sativus*).

IN 1985, scientists published the first two papers addressing the potential environmental impacts of genetically engineered crops. California scientists played important roles in writing both. Senior personnel at CalGene, a California-based genetic engineering firm, wrote one paper (Goodman and Newell 1985), and a UC Berkeley faculty member was senior author of the other (Colwell et al. 1985). Both articles prominently featured the possibility that hybridization could serve as an avenue for the unintended movement of engineered genes (transgenes) from transgenic crops into populations of related weeds. Such movement of genes between species or populations, called "gene flow," in itself does not pose a risk. Gene flow by pollen and seed between cross-compatible populations is not uncommon, and often plays an important role in both evolution and plant breeding (Ellstrand 2003a).

Both papers pointed out that the presence of crop genes in wild populations has long been recognized as a stimulus for the evolution of increased weediness or "superweeds" (Anderson 1949). Goodman and Newell (1985) stated the problem succinctly: "The sexual transfer of genes to weedy species to create a more persistent weed is probably the greatest environmental risk of planting a new variety of crop species."

Other potential environmental problems of transgenic crops were anticipated and discussed in those articles (see sidebar, page 119), but the risks associated with the unintentional movement of engineered genes into populations for which they were not intended continue to receive the most attention in both scientific publications and the popular press. This attention may stem, in part, from the fact that the movement of unwanted crop genes into the environment poses more of a management

dilemma than unwanted nonliving "pollutants." For example, a single molecule of DDT remains a single molecule or degrades. But a single crop allele occurs within an organism that may have the opportunity to multiply itself — and that allele — repeatedly through reproduction. The fact that unwanted genes can increase their numbers could frustrate attempts at recall or containment. Indeed, almost every general treatment of the environmental impacts of plant biotechnology gives some consideration to gene flow (Dale et al. 2002; Hails 2000; Marvier 2001; NRC 1989, 2000, 2002, 2004; Nickson and Head 1999; Rissler and Mellon 1996; Scientists' Working Group on Biosafety 1998; Snow et al. 2005; Wolfenbarger and Phifer 2000), and a book on the topic was recently published (den Nijs et al. 2004).

Over the last 17 years, my research program has evolved to focus on the topic, addressing the following questions: How likely is it that transgenes will move into and establish in natural populations? And if transgenes do move into wild populations, is there any cause for concern? Traditionally improved crops can serve as models for the behavior of transgenic crops; indeed, the U.S. regulatory framework for transgenic plants is based on this assumption (NRC 1989, 2002). Experience with traditional crops and experiments using them can provide a tremendous amount of information for answering these questions.

Spontaneous hybridization study

In the early 1990s, the general view was that hybridization between crops and their wild relatives occurred extremely infrequently, even if they were growing in close proximity. This view was probably due to the difficulties breeders sometimes have in creating crop-wild hybrids (Fehr 1987). My research group set out to measure spontaneous hybridization between wild radish (*Raphanus sativus*), an important California weed, and cultivated radish (the same species), an important California crop (Klinger et al. 1991). (It is not unusual for a crop to be closely related to a weed of the same species.)

In 1988 and 1989, we grew the crop as if we were multiplying commercial seed and surrounded it with stands of

GLOSSARY

Allele: Type of a gene. For example, the common gene involved in human blood typing involves three alleles: A, B and O.

Allozyme: Allelic protein products of a single gene that can be visualized with starch gel electrophoresis and subsequent appropriate staining.

Cultivated and wild types: Cultivated crops may have an array of wild relatives. (See box below.)

Fitness: Reproductive success as determined by survivorship and fecundity.

Gene flow: Migration of genes among populations. In humans, this involves migration of individuals. In plants, it may also involve pollen or seed movement.

Hybridization: Crossing among individuals from genetically distinct lineages. (See box below.)

Outcrossing: Reproduction that involves crossing between two different individuals. In humans and many animals, all reproduction is due to outcrossing. In some plants and animals, self-fertilization (selfing) is also an option, as well as reproduction without fertilization (asexuality).

Phenotype: Trait or traits expressed by an organism.

Taxon (taxa): Taxonomic unit, such as species or subspecies.

A CLOSER LOOK

At hybridization . . .

Hybridization refers to crosses between individuals of different but related species. When this is the case, there are reproductive, isolating barriers that either reduce the chances of mating, such as differences in flowering, or reduce the chances of progeny passing on their genes, such as hybrid sterility (for example, the mule is a hybrid between the horse and the donkey, two separate species). Reproductive isolating barriers may be minimal or absent in the cases of hybridization between subspecies, between different varieties of the same crop, or between cultivated crops and crops that have gone wild (feral). Plant breeders often intentionally make artificial crosses to transfer beneficial traits. Spontaneous, natural hybridization is relatively rare in animal species, but is more common for plants.

. . . and cultivated versus wild type

Plants that are intentionally cultivated as crops may have an array of wild relatives. Some wild relatives may be the progenitors of the crop or other taxa whose ancestors were not cultivated. Also, some crops establish free-living (feral) populations. These populations may take off on their own evolutionary trajectory to become weeds of varying importance. In some cases, a single gene difference, such as bolting in beets, can change a crop into a weed. Finally, for many crops there are wild, weedy relatives that are descended from hybrids between cultivated plants and wild individuals without cultivated ancestors.

— N.C. Ellstrand

IANR Photo, © University of Nebraska, Lincoln, 2001

Jack Kelly Clark

Right, **sorghum is an important global food-grain crop, while its wild relative, *far right,* johnsongrass (*Sorghum halepense*), is one of U.S. agriculture's most troublesome weeds. Sorghum and johnsongrass have different numbers of chromosomes, but UC scientists found that they spontaneously hybridized when grown within 330 feet of each other.**

weeds at varying distances. When the plants flowered, pollinators did their job. We harvested seeds from the weeds for progeny testing. We exploited an allozyme allele that was present in the crop and absent in the weed to detect hybrids in the progeny of the weed. The experiment was repeated at the UC South Coast Research and Extension Center and at the UC Riverside Moreno Valley Field Station. At both locations, we found that many of the weed seeds analyzed at the shortest distance of 3.3 feet (1 meter) were sired by the crop (40% hybridization), and that a low level (about 2%) of hybridization was detected at the greatest distance of 0.62 mile (1 kilometer). It was clear, at least in this system, that crop alleles could enter natural populations.

But could they persist? The general view at that time was that hybrids of crops and weeds would be handicapped by crop characteristics that are agronomically favorable, but a detriment in the wild. The expectation was that crop-wild hybrids should have inferior fitness in the wild, compared to their wild parents.

We tested that view by comparing the fitness of the hybrids created in our first experiment with their nonhybrid siblings (Klinger and Ellstrand 1994). We grew them side by side under field conditions. The hybrids exhibited the huge, swollen root characteristic of the crop, but the pure wild plants did not. The two groups did not differ significantly in germination, survival or ability for their pollen to sire seed. However, the crop-wild hybrids set about 15% more seed than the wild plants. In this system, hybrid vigor would accelerate the spread of crop alleles in a natural population.

Exception to the rule?

When I presented these results at seminars, scientists questioned the generality of the results. "Isn't radish probably an exception?" they asked. "After all, radish is outcrossing and insect-pollinated. Its wild relative is the same species. What about a more important crop? What about a more important weed?"

We decided to address these criticisms with a different combination of crop and wild relative. Sorghum (*Sorghum bicolor*) is one of the world's most important crops, and johnsongrass (*S. halepense*) is one of the world's worst weeds. The two are distinct species, even differing in chromosome number, and sorghum is largely self- and wind-pollinated. The sorghum system was about as different from radish as you could get.

We conducted experiments with sorghum that paralleled those conducted with radish. We found that sorghum and johnsongrass spontaneously hybridized, although at rates lower than the radish system, and we detected crop alleles in seed set by wild plants growing 330 feet (100 meters) from the crop (Arriola and Ellstrand 1996). The fitness of the hybrids was not significantly different from their wild siblings (Arriola and Ellstrand 1997). The results from our sorghum-johnsongrass experiments were qualitatively the same as those from our cultivated radish–wild radish experiments.

Other labs have conducted similar experiments on crops such as sunflower (*Helianthus annuus*), rice (*Oryza sativa*), canola (*Brassica napus*) and pearl millet (*Pennisetum glaucum*) (Ellstrand 2003b; den Nijs et al. 2004). Almost all such studies obtained qualitatively similar results to those obtained by my research group. There are a few exceptions; for example, experiments have shown that potato (*Solanum tuberosum*) does not naturally mate with the wild species *S. dulcamara* and *S. nigrum* under field conditions (McPartlan and Dale 1994).

Additionally, descriptive studies conducted in my lab and others have often found crop-specific alleles in wild relatives when the two grow in proximity. In California, alleles from sugarbeets are found in populations of the wild beet *Beta macrocarpa* in the sugarbeet production region of the Imperial Valley, where the latter is a weed in and near sugar-

— continued on page 121

Scientists evaluate potential environmental risks of transgenic crops

Norman C. Ellstrand

Stephen Ausmus/USDA-ARS

Genetic engineering has been used to modify all of the crops and products shown, although most are not commercially available. The environmental risks of growing transgenic crops could include pest resistance and unintended effects on nontarget species, such as increased weediness among similar wild plants.

A relatively small group of scientists — including some Californians — have taken a hard and thoughtful look at the potential risks of transgenic crops. These varied scientists — including ecologists, soil biologists, agronomists, geneticists, entomologists, pathologists, horticulturists, botanists and molecular biologists — realize that traditional plant improvement and agriculture have, on occasion, created problems, and those problems can serve as models for anticipating the possible downsides of transgenic crops. A set of straightforward, scientifically based concerns has evolved. The most widely discussed concerns fall into two broad categories: (1) problems created directly by growing the crops themselves, and (2) problems created by unintended descendants of those crops.

Environmental biosafety is a relatively new and rapidly developing research area. An excellent source of information on this field is the National Research Council's (NRC 1989, 2000, 2002, 2004) series of peer-reviewed reports on the potential environmental impacts of agricultural biotechnology. The most up-to-date information can be found in peer-reviewed, disciplinary journals such as *Environmental Biosafety Research, Ecological Applications* and *Molecular Ecology.*

Direct impacts of crops themselves

Scientific consideration of the direct impacts of transgenic crops has focused almost exclusively on the evolution of pests that are resistant to new strategies for their control, and unwanted impacts on species in associated ecosystems. Another area of concern is the unwanted impacts on surrounding plant and animal communities from the use of transgenic herbicide-resistant plants (Firbank et al. 2003). Resistance to one or more herbicides is a general feature of most crops; also, resistance to herbicides can often be obtained through nontransgenic techniques (Duke et al. 1991). The impact of herbicide-resistant crops on surrounding community diversity depends largely on the type of herbicide, and where and how it is used.

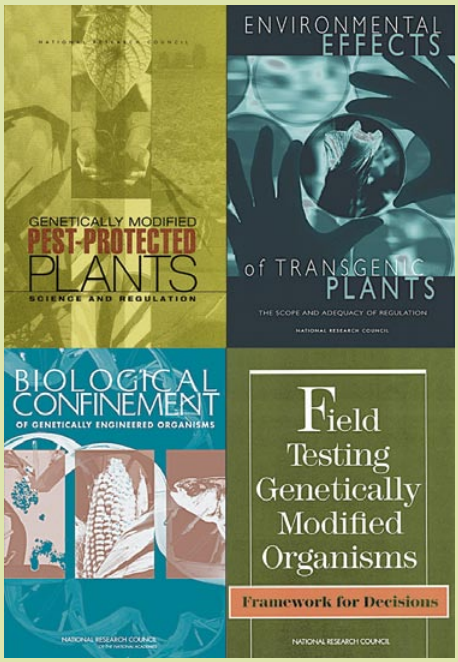
Evolution of resistant pests. Insects, weeds and microbial pathogens often evolve resistance to controls used against them (Barrett 1983; Georghiou 1986; Green et al. 1990). When a pest evolves the ability to attack a crop, the results sometimes can be devastating. The 1970 corn leaf blight epidemic ravaged American cornfields, resulting in the loss of tens of millions of dollars to the industry (NRC 1972).

Resistance evolution is also expected to occur in pests targeted for control by or associated with transgenic crops. Although the evolution of resistance is a continuous process, the evolution of resistant pests has been considered a potential environmental hazard of transgenic crops because more environmentally damaging alternative treatments would then be needed for control. Furthermore, transgenic products at present have resulted in the use of a single, uniform control method over huge areas.

For example, most of the transgenic corn and cotton now grown in the United States, millions of acres, is engineered with a bacterial gene that allows them to manufacture their own pesticide to specifically target certain insect pests. Because the gene comes from the bacterial species known as *Bacillus thuringiensis*, these plants are commonly known as "Bt corn" and "Bt cotton." Bt cotton is the most important transgenic crop in California (Taylor et al. 2004). Because the transgenic product does not kill all insect species, it is considered relatively environmentally benign. But the evolution of resistance to Bt crops is considered inevitable (NRC 2000). The U.S. Environmental Protection Agency has issued guidelines mandating that farmers plant "refuges" of non-Bt varieties in plantations of Bt varieties to prevent or delay the evolution of resistance. Despite the commercialization of Bt crops for almost a decade, no pests have yet evolved resistance to Bt crops in the field, suggesting that the refuge strategy has been effective (Tabashnik et al. 2003).

Effects on nontarget species. A crop engineered to interfere with the reproduction or viability of one or more pest species might also interfere with other nonpest species. For example, Bt corn was developed to control certain moth species that damage the crop. Reports of potentially toxic effects of Bt corn pollen and flower parts eaten by monarch butterfly larvae captured widespread attention (Losey et al. 1999). A flurry of subsequent research demonstrated that the effects of Bt pollen on monarch larvae are highly variable, depending on factors such as pollen density, the crop's Bt genotype and environmental factors (Sears et al. 2001). Current commercial Bt corn varieties are not considered hazardous to monarch larvae, but one variety no longer grown would have been. This example illustrates that risk assessment research can clarify whether a putative risk is, in fact, a problem.

But is this a new environmental problem? One might ask, "Isn't it better



The National Research Council has published numerous science-based reports on the environmental risks and benefits of transgenic plants and food.

to deploy a pesticide through a plant that kills only a subset of insects than to spray one on a field that kills all insects willy-nilly?" The answer, of course, would be, "Yes, Bt in corn reduces environmental impacts relative to spraying broad-spectrum insecticides." However, prior to the advent of Bt corn, many American corn farmers did *not* spray insecticides to control the pests controlled with Bt (NRC 2000). Those farmers simply took their chances without any control, possibly because the damage from the lepidopteran pests of corn varies so much from one year to the next. In the latter comparison, the addition of Bt, if it carries adverse nontarget effects, does pose a new problem.

Unintended crop descendants

All plants — including crops — are capable of some type of reproduction. The possibility of unintended reproduction by transgenic crops has raised questions about whether their descendants might cause problems. These problems have fallen into two broad categories: first, that the direct feral descendants of the crops may prove to be new weeds or invasives, and second, that unintended hybrids between transgenic crops and other plants could lead to certain problems.

If deregulated and grown widely, these potential future crops will require further scrutiny for possible gene-flow problems.

Progeny of the transgenic crop could become a problem if the transgenic trait alters their ecological performance such that they evolve increased aggressiveness. Some crop plants — especially those with a long history of domestication (e.g., corn and soybeans) — pose little hazard because traits that make them useful to humans also reduce their ability to establish feral populations in either agroecosystems or nonagricultural habitats (NRC 1989). But other cultivated plants (e.g., certain forage grasses and turf grasses, ornamentals, rice, rye, alfalfa) often volunteer after cultivation, founding feral populations that create problems (Gressel 2005). In some cases, the tendency to found feral populations could increase as the result of acquiring new traits.

The factors that foster or limit invasiveness are not well understood (Sakai et al. 2001). Most of the current transgenic crop traits — insect, virus and herbicide resistance — are expected to confer a fitness advantage in certain environments. Empirical evolutionary-genetics studies have demonstrated that a new allele that confers a fitness advantage will usually spread rapidly through a population, but it will not necessarily result in the evolution of invasiveness (Bergelson 1994). The mere presence of a transgene that increases fitness cannot be taken as certainty that the invasiveness of a population has increased. Many crops are unlikely to become weedier by the addition of a single trait (Keeler 1989). In a few cases, however, the consequences might be obvious. The evolution of herbicide resistance in a weed population that was previously controlled by that chemical will force the consideration of new control options.

Scientifically based assessment

Genetically engineered crops are a heterogeneous group. It is no more reasonable to lump them all together to argue that, as a group, they pose an environmental danger than it is to lump them all together to argue that, as a group, they will feed the world and cure disease. It is fair to say that just like the products of traditional plant improvement, certain products of genetic engineering will create problems. To the extent that those products can be compared to traditionally improved plants, scientifically based hazards can be identified.

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— *continued from page 118*

beet fields (Bartsch and Ellstrand 1999). Likewise, genetic analysis of putative spontaneous hybrids has demonstrated that cultivated grape mates with wild grape species in California (Olmo and Koyama 1980). The data from such descriptive studies and experiments provides ample evidence that if cultivated plants and their wild relatives occur in close proximity, occasional spontaneous hybridization is not unusual. This phenomenon is a general feature of most of the world's important crops, from avocado to corn, and soybean to mushrooms (Ellstrand 2003b; den Nijs et al. 2004). Even the sorghum-johnsongrass results, involving a crop so different from a wild relative that their chromosome numbers are different, have not been shown to be an exceptional case.

Amadej Trnkoczy

Scott Bauer/USDA-ARS

While crop-to-wild plant gene flow has been widely documented in numerous combinations, an exception is, *bottom,* potato (*Solanum tuberosum*), which does not naturally cross with the wild related species, *top,* European bittersweet (*Solanum dulcamara*) under field conditions.

Impacts of natural hybridization

When I gave seminars on the results of these studies, I was met by a new question: "If gene flow from crops to their wild relatives is going to be a problem for crops improved by genetic engineering, then wouldn't such problems already have occurred for species improved by traditional, nontransgenic methods?" A good question. I conducted a thorough literature review to find out what was known about the consequences of natural hybridization between the world's most important crops and their wild relatives, a multiyear odyssey of digging through diverse literature and interviewing dozens of the world's experts on important crops and their wild relatives (Ellstrand 2003b).

I found that on occasion, crop-to-weed gene flow has created hardship through the appearance of new or more-difficult weeds. Hybridization between wild plants and their cultivated relatives has been implicated numerous times in the evolution of new weeds or the evolution of increased weediness in pre-existing weeds (Ellstrand 2003b). Especially notable is Europe's new weed beet, the spontaneous hybrids between sea beet (*Beta vulgaris* subsp. *maritima*) and sugarbeet (*B. vulgaris* subsp. *vulgaris*) and their descendants. This weed has cost Europe's sugar industry well over a billion dollars in reduced yields, damaged machinery and control costs (den Nijs et al. 2004; Ellstrand 2003b; Parker and Bartsch 1996).

Crop-to-wild gene flow can create another problem. Theoretical models have demonstrated that hybridization between a common species and a rare one can, under the appropriate conditions, send the rare species to extinction in a few generations (Ellstrand and Elam 1993; Huxel 1999; Wolf et al. 2001). In several cases, hybridization between a crop and its wild relatives has increased the extinction risk for the wild taxon (Ellstrand 2003b). One example is the extinction of a wild subspecies of rice in Taiwan (Kiang et al. 1979). Furthermore, Ledig (1992) reported that in California, "pollen contamination from cultivated walnut may hybridize the (endangered) Hinds walnut out of existence."

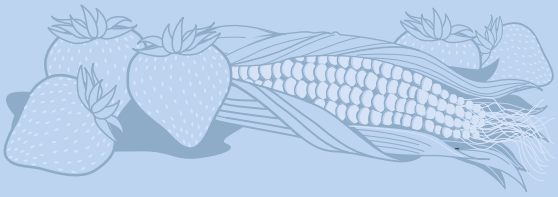
The vast majority of cases of spontaneous hybridization between cultivated plants and their wild relatives are of little consequence. But clearly gene flow from crops to wild relatives has, on occasion, had undesirable consequences.

Are transgenic crops likely to be different from traditionally improved crops? No, but that is not necessarily good news. The probability of problems due to gene flow from any individual cultivar is extremely low. But when those problems are realized, they can sometimes be costly.

New transgenic cultivars

As a group, new transgenic cultivars are no more or less likely to hybridize than their nontransgenic counterparts (Ellstrand 2003b; den Nijs et al. 2004). Whether transgenic crops are more or less likely to create gene-flow problems will depend in part on their phenotypes, the traits for which they were engineered. The majority of "first generation" transgenic crops have phenotypes — such as herbicide or pest resistance — that are apt to give a weed a fitness boost in certain environments. Although a fitness boost in itself may not lead to increased weediness, scientists engineering crops with such traits

TABLE 1. Transgenic crops approved for field-testing in California through Jan. 16, 2006*



Crop	Transgenic status	Scientific name	Among state's top 20 crops in 2003 area harvested?†	Wild or feral form of species in Calif.?	Wild species known to hybridize with crop in Calif.?	Are hybridizing plants weeds (W) or rare (R) in Calif.?‡
Alfalfa	Some deregulated, commercialized types	*Medicago sativa*	Yes	Yes	No	N/A
Apple	Regulated only	*Malus* x *domestica*	No	Yes	No§	N/A
Avocado	Regulated only	*Persea americana*	Yes	No	No	N/A
Barley	Regulated only	*Hordeum sativum*	Yes	No	No§	N/A
Beet	Some deregulated types, but none presently commercialized	*Beta vulgaris*	No	Yes	Yes	W
Brassica (broccoli, cabbage, etc.)	Regulated only	*Brassica oleracea*	Yes	No	No§	N/A
Brown mustard	Regulated only	*Brassica juncea*	No	Yes	Yes	W
Canola	Some deregulated, commercialized types	*Brassica napus*	No	Yes	Yes	W
Carrot	Regulated only	*Daucus carota*	Yes	Yes	No§	W
Chicory	Some deregulated types, but none presently commercialized	*Cichorium intybus*	No	Yes	No§	W
Chrysanthemum	Regulated only	*Dendranthema grandiflora*	No	No	No	N/A
Corn	Some deregulated, commercialized types	*Zea mays*	Yes	No	No	N/A
Cotton	Some deregulated, commercialized types	*Gossypium hirsutum*	Yes	No	No	N/A
Creeping bentgrass	Regulated only	*Agrostis stolonifera*	No	Yes	Yes	W
Cucumber	Regulated only	*Cucumis sativus*	No	No	No§	N/A
Grape	Regulated only	*Vitis vinifera*	Yes	No	Yes	No
Hybrid tea rose	Regulated only	*Rosa hybrida*	No	No	No§	N/A
Kentucky bluegrass	Regulated only	*Poa pratensis*	No	Yes	Yes	No
Lettuce	Regulated only	*Lactuca sativa*	Yes	No	Yes	W
Melon	Regulated only	*Cucumis melo*	Yes	Yes	No§	W
Onion	Regulated only	*Allium cepa*	No	No	No§	N/A
Pea	Regulated only	*Pisum sativum*	No	Yes	No	No
Pelargonium	Regulated only	*Pelargonium* x *hortorum*	No	Yes	No	No
Pepper	Regulated only	*Capsicum annuum*	No	No	No	N/A
Persimmon	Regulated only	*Diospyros kaki*	No	No	No	N/A
Petunia	Regulated only	*Petunia* x *hybrida*	No	No	No§	N/A
Potato	Some deregulated types, but none presently commercialized	*Solanum tuberosum*	No	No	No§	N/A
Raspberry	Regulated only	*Rubus idaeus*	No	No	No§	N/A
Rice	Some deregulated types, but none presently commercialized	*Oryza sativa*	Yes	Yes	No	W
Soybean	Some deregulated, commercialized types	*Glycine max*	No	No	No	N/A
Squash	Some deregulated, commercialized types	*Cucurbita pepo*	No	No	No§	No
St. Augustine grass	Regulated only	*Stenotaphrum secundatum*	No	Yes	No	No
Strawberry	Regulated only	*Fragaria ananassa*	No	No	Yes	No
Sunflower	Regulated only	*Helianthus annuus*	No	Yes	Yes	W
Tobacco	Some deregulated types, but none presently commercialized	*Nicotiana tabacum*	No	No	No§	N/A
Tomato	Some deregulated types, but none presently commercialized	*Lycopersicon esculentum*	Yes	Yes	No§	No
Walnut	Regulated only	*Juglans regia*	Yes	No	Yes	R
Watermelon	Regulated only	*Citrullus lanatus*	No	Yes	No	No
Wheat	Regulated only	*Triticum aesitivum*	Yes	No	Yes	W

* Based on USDA-approved permits or acknowledged notifications (ISB 2006).

† Source: Hickman 1993.

‡ Sources: Whitson 2000; Hickman 1993.

§ One or more congeners present in California. For some of these, whether spontaneous hybridization with the crop occurs is still unknown.

should be mindful that those phenotypes might have unwanted effects in natural populations.

The crops most likely to increase the extinction risk by gene flow are those planted in new locations that bring them into the vicinity of wild relatives, thereby increasing the hybridization rate because of proximity. For example, a new variety with increased salinity tolerance might be planted within the range of an endangered salt-tolerant relative. It is clear that scientists creating new crops for field release, transgenic or otherwise, should consider the possibility of gene flow when making choices about whether it might create problems, and if so, how to create the best and safest products (NRC 2004).

Risks to California

But how likely is it that transgenes will flow to wild plants in California? At the moment, only seven different crops with genetically engineered varieties are commercially available in the United States: canola, corn, cotton, papaya, soybean, squash and tobacco. In California, five of these have no closely related wild relatives: corn, cotton (California's primary transgenic crop), papaya (which cannot be grown outdoors in California) and squash. These plants do not even establish feral populations in California. Furthermore, transgenic tobacco is not grown in California. For these six crops, gene flow into the wild in California is not possible. (As this article is going to press, genetically engineered alfalfa was deregulated for probable commercialization in California.)

Transgenic canola (*Brassica napus*) or "oilseed rape" is a different story. A tremendous amount of interspecies gene-flow research, both descriptive and experimental, has been conducted on this species in the United States, Canada, United Kingdom, France and Denmark (Ellstrand 2003b; den Nijs et al. 2004). *Brassica napus* naturally and easily intermates with wild *B. rapa* and, to a much more limited extent, with a few other mustard family species. Most of those species, including *B. rapa*, occur in California where they are known to be problematic weeds (Whitson 2000). Experiments have demonstrated that the hybrids between canola and

Keith Weller/USDA-ARS

Golden Rice Humanitarian Board

Due to market concerns, California rice growers are cautious about adopting transgenic crops that could cross with conventional varieties. *Left,* U.S. long-grain rice and, *top right,* rice grains. *Lower right,* "golden rice" is genetically engineered to accumulate pro-vitamin A in the grain, in order to help fight nutritional deficiency diseases in developing countries.

B. rapa typically have a drop in fitness relative to their parents, but that fitness is rapidly regained when those hybrids mate with one another or backcross to either parent. Only two genetically engineered types of canola are commercially available in the United States: plants engineered with resistance to the herbicide glyphosate and those engineered with resistance to the herbicide glufosinate.

Interestingly, the first and only reported case of spontaneous hybridization between a commercial transgenic crop and a wild relative involved genetically engineered glyphosate-resistant canola and *B. rapa*, in Quebec (Warwick et al. 2003). The hybrid plants were found where the wild species were growing in or adjacent to glyphosate-resistant canola.

The appearance of glyphosate resistance in *B. rapa* could present a problem if it forces farmers — who control this weed with relatively inexpensive and relatively environmentally benign glyphosate — to abandon it in favor of an alternative herbicide without those benefits. Whether or not the Quebec hybrids become a problem is currently under study by the group that discovered them. However, canola is not an important, or even significant, California crop. Furthermore, the adoption of transgenic canola has not been nearly as enthusiastic in the United States as it has been for soybeans, corn and cotton. The majority of the U.S. canola crop remains non-transgenic. Therefore, the opportunities for the canola transgene to spread in California are much more limited than in Canada, where it is one of the most important crops.

The future of plant biotech

The face of plant biotechnology is rapidly changing. Dozens of genetically engineered crop species have been field-tested. Crops field-tested under U.S. Department of Agriculture / Animal and Plant Health Inspection Service (USDA-APHIS) notification or permit are required to be grown with some level of containment (NRC 2002). If the growers comply with those regulations, field-tests should not present an opportunity for transgene escape. Nonetheless, such crops represent the pool for new commercial transgenic crops of the next decade. As of Jan. 16, 2006, 1,215 field-test applications had been approved for 39 crops in California (table 1) (ISB 2006). The applications are for hundreds of different crop-trait combinations, from fungal-disease-resistant avocado to pharmaceutical-producing rice.

More than half of the 39 field-tested crops have wild relatives in the California flora with which they are capable of hybridizing — either as wild plants that are same species or as closely related species known to spontaneously hybridize with the crop (table 1). In 11 cases, those wild plants are considered weeds in California. Fourteen of the field-tested crops rank among the top 20 California crops in terms of acreage harvested; 10 have cross-compatible mates in the wild flora of California. If deregulated and grown widely, these potential future crops will require further scrutiny for possible gene-flow problems. For example, wheat spontaneously hybridizes with a number of known weeds in the genus *Aegilops* that grow wild in California. Whether the movement of transgenes into the wild will create problems depends on the specific transgenic-based trait and how it is expressed in the wild populations (Ellstrand 2003b).

Compared to crop-to-wild transgene movement, crop-to-crop movement is much more likely. Different varieties of the same crop are usually fully sexually compatible. It is not unusual for adjacent and simultaneously flowering fields of the same crop to cross-pollinate. Also, gene flow by seed becomes an issue in this context. Unless very carefully segregated, seed from different varieties often becomes mixed during seed production. If a seed bank persists in the soil, individuals from last year's planting can appear within this year's crop. If a transgene moves unintended from one field of a crop to another of the same crop, a number of adverse consequences are possible, including: the loss of security for intellectual property; effects on nontarget organisms in natural or agroecosystems; and the evolution of new weeds.

Genetic pollution of crops

"Genetic pollution" may occur in crops intended to have a certain level of purity with regard to market demands — for example, crops certified as organic or intended for foreign markets that do not tolerate the presence of materials from genetically engineered plants. Health effects may be possible if genes engineered

to produce pharmaceutical or industrial compounds enter the food or feed supply. Such plants are required to be grown only under stringent field-test regulations. However, lack of compliance (NRC 2004; Taylor and Tick 2003) can create opportunities for such genes to move. Little has been written regarding the possible downsides of crop-to-crop gene flow involving transgenic plants, but recent incidents suggest that much more attention should be paid to this risk.

Herbicide resistance in canola. For example, multiple herbicide resistance developed in canola in Alberta, Canada (Hall et al. 2000). Volunteer canola plants were found to be resistant to two or more of the following herbicides: glyphosate (Roundup: Monsanto, St. Louis; Mo.), glufosinate-ammonium (Liberty: Aventis Crop Science, Research Triangle Park, N.C.) and imazethapyr (Pursuit: BASF, Research Triangle Park, N.C.). Clearly, multiple hybridization events among three different canola varieties were necessary to account for these genotypes. The alleles for resistance to glyphosate and glufosinate-ammonium are transgenes, but the allele for imazethapyr resistance is the result of mutation breeding. Although these volunteers can be managed with other herbicides, this report is significant because it illustrates that gene flow into wild plants is not the only avenue for the evolution of plants that are increasingly difficult to manage.

Starlink corn. A better-known incident involved Starlink corn (NRC 2004; Taylor and Tick 2003). The Starlink gene and its product were approved only for animal feed, not human consumption. However, Starlink's genetically engineered protein appeared in a variety of products intended for human consumption. USDA detected the protein in over 10% of the corn samples initially screened, none of which were supposed to contain Starlink material. Although unintentional mixing of seeds during transport or storage may explain the unexpected presence of the unapproved transgenic product in the human food supply, intervarietal cross-pollination between adjacent cornfields probably played an important role as well. The story is significant because it illustrates how easy it is to lose track of transgenes. Without careful confinement and monitoring, there are plenty of opportunities for them to move from variety to variety (Christensen et al. 2005; NRC 2004).

If the two preceding incidents were the only examples of transgenes showing up where they shouldn't, they could be considered anomalous. But they are only a tiny sample of an increasing number of such events. For a decade, more than a dozen cases of transgenes and/or their products out-of-place have been reported (Marvier and Van Acker 2005).

Gene flow in itself is not necessarily a problem, but unless specific steps are taken to isolate transgenic crops, the movement of transgenes to nontransgenic crops should not be an unusual occurrence. In fact, the frequency of these events has led some scientists to write, "the movement of transgenes beyond their intended destination is a virtual certainty" (Marvier and Van Acker 2005).

While organic crops must be transgene-free, cross-contamination of organic cotton by transgenic varieties is not expected to be a problem because seeds (which may contain genes from an engineered pollen parent) are removed from the lint (which is pure maternal tissue). *Left,* a cotton crop; *right,* baby clothes made with organic cotton.

A problem for California?

Organic farming. If crop-to-crop gene flow is a "virtual certainty," which of its possible downsides are more likely to prove to be a problem in California? The issue of "coexistence" of genetically engineered crops with organic farming may be the most important (Schiemann 2003). The organic sector of California agriculture is rapidly growing. Organic crops are required to be transgene free. Presently, the onus for isolation is put on the organic grower. If transgenic crops pollinate organic crops, then their seed will bear transgenes. Of California's current major transgenic crops, this would not pose a problem for organic cotton because the seeds are removed from the lint, which is maternal tissue; on the other hand, farmers growing organic corn would have to practice some form of isolation to prevent them from being pollinated by nearby transgenic fields. Seed-source purity would be an important factor for growers of either organic cotton or organic corn. As more crops are deregulated and grown in California, the issue will continue to grow, especially for crops that are widely planted in the state.

Pharmaceutical crops. Transgenic crops that are grown to produce pharmaceutical and other industrial biochemicals pose another potential problem. These will pose special challenges for containment if we do not want those chemicals appearing in the human food supply. In the last 5 years, nine field-test applications of such plants were approved for California.

We know that it is easy to lose track of transgenic genes — if pollen moves

farther than expected, if seeds stay in the soil ungerminated or if seed are inadvertently mixed. The mixing of genes between different varieties of the same crop is a lot easier than the flow of genes into the wild, but both can have their downsides.

Weighing risks and benefits

In most cases, transgenes will not need to be contained. But sometimes containment will be helpful or necessary. New methods must be developed because present agronomic protocols are not always sufficient to do the job. New segregation procedures are being proposed (Christensen et al. 2005; Strayer 2002). Likewise, engineered constructs and other genetically based methods are being studied to effect containment (NRC 2004). All of these methods seem promising and need to be tested.

In the meantime, the creators of transgenic plants need to be as mindful of possible problems with their products as they are of potential promise. The best confinement should be upfront, with decisions made at the start of a project. In at least three cases that this author is aware of, scientists decided to stop engineering certain traits into certain crops because of anticipated problems with gene flow. But stopping a project altogether may be unnecessary. Often, a good decision will involve consideration of the safest combination of trait and organism. At one time corn was the organism of choice as a "pharm" plant. Today other plant species, often nonfood species, are being explored for this use.

The products of traditional plant improvement are not absolutely safe, and we cannot expect transgenic crops to be absolutely safe either. If we have advanced tools for creating novel agricultural products, we should use the advanced knowledge from ecology and population genetics — as well as social sciences and humanities — to make mindful choices about creating products that are best for us and our environment.

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Careful risk assessment needed to evaluate transgenic fish

by Alison L. Van Eenennaam *and* Paul G. Olin

www.glofish.com

GloFish, a zebra danio that produce a red fluorescent protein, are the only transgenic fish that are commercially available in the United States. However, these aquarium fish are not available in California, which requires permits for the possession of genetically engineered fish.

The reproductive biology of fish makes them particularly amenable to genetic manipulation. A genetically engineered or "transgenic" Atlantic salmon is currently undergoing federal regulatory review, and international research is being conducted on many other species. The innate ability of fish to escape confinement and potentially invade native ecosystems elevates the ecological concerns associated with their genetic modification. Escaped transgenic fish will not invariably result in deleterious effects on native populations, and careful risk assessment is required to determine the ecological risks unique to each transgene, species and receiving ecosystem combination. In response to public concerns about transgenic fish, California has developed stringent regulations for the importation, possession and raising of transgenic fish, and a California law prohibits their presence in waters of the Pacific Ocean regulated by the state.

The rationale for developing transgenic or genetically engineered animals for agricultural applications is essentially to increase their productivity and yield, improve their resistance to diseases and parasites, and enhance the nutritional and processing qualities of foods derived from these transgenic animals. Compared with mammals, fish offer important advantages for the production of transgenics because of the large number of eggs laid per female, the fact that fertilization and embryonic development takes place outside the mother (in most species), the lower probability of carrying human pathogens, and the fact that aquaculture is a rapidly expanding market. The first transgenic fish were produced in 1984, and since that time more than 30 species have been genetically engineered worldwide (table 1).

The number of transgenic species is higher for fish than for all other vertebrate species combined. Transgenic fish have been developed for applications such as the production of human therapeutics, experimental models for biological research, environmental monitoring, ornamental fish and aquacultural production. Ironically, in addition to being the taxonomic group with the most transgenic species, aquatic organisms are also the most likely group to present environmental concerns if accidentally released into the environment. Unlike most other agricultural species, fish are both difficult to contain and highly mobile, and they can easily become feral and invade native ecosystems (NRC 2002).

Transgenic fish defined

Transgenic fish are those that carry and transmit one or more copies of a recombinant DNA sequence (i.e., a sequence produced in a laboratory using in vitro recombinant DNA techniques). They are defined by the technology that is used to create and transfer the DNA sequence, not the source species of the donor DNA. Therefore, fish engineered with recombinant DNA derived entirely from fish are considered transgenic.

The recombinant DNA sequence, or construct, is usually comprised of several different regions including a start signal or "promoter," the coding region for the target protein, and a stop signal or "terminator." The construct is usually introduced into the animal's genome through microinjection of the recombinant DNA fragment into fertilized eggs or early embryos.

Inducing transgenesis is a relatively inefficient process. Only about one out of every 100 eggs microinjected will stably incorporate the recombinant DNA sequence into its genome and subsequently transmit the transgene to its progeny. The growth hormone gene has been the most popular target gene for transgenesis, which is not surprising considering the potential cost savings in feed for such a product. At least 14 species of fish have been genetically modified for enhanced growth, and although they almost always grow faster than nontransgenic controls, they do not necessarily grow to a larger mature size.

There are, however, some startling examples of gigantism (Nam et al. 2001).

GLOSSARY

Agonistic: Combative, striving to overcome.

A priori: Knowledge, judgments and principles that can be established independent of verification or testing.

Genetic engineering: The transfer of recombinant DNA sequences into the genome of a living organism.

Genome: The total DNA in a single cell, representing all of the genetic information of the organism. The normal human genome consists of 23 chromosomes from each parent.

Genotype: The entire genetic constitution of an organism, or the genetic composition at a specific gene locus or set of loci.

Meiosis: A special type of cell division by which eggs and sperm cells are made, involving reduction from a diploid (double) to a haploid (single) chromosome set.

Recombinant DNA: The laboratory manipulation of DNA in which DNA, or fragments of DNA from different sources, are cut and recombined using enzymes.

Transgene: A piece of DNA, typically a gene produced by recombinant DNA techniques, that is introduced into cells or organisms to modify the genome.

Transgenesis: The introduction of a recombinant DNA sequences into the genome of a living organism, leading to the transmission of the transgene to successive generations (see Genetic engineering).

Transgenic: An organism that has recombinant DNA in its genome. A transgenic organism is said to have been "genetically engineered."

TABLE 1. Examples of transgenes introduced into fish that cause significant phenotypic effects*

Phenotype targeted	Species	Transgene
Growth (> twofold)	Atlantic salmon Tilapia Rainbow trout Coho salmon Chinook salmon Rohu Loach	Growth hormone
Freeze tolerance	Atlantic salmon	Antifreeze protein
Disease resistance	Catfish Carp Medaka	Cecropin Lactoferrin Cecropin
Carbohydrate metabolism	Rainbow trout Rainbow trout	Glucose transporter Hexokinase
Reproduction	Rainbow trout	Antisense GnRH
Lipid metabolism	Zebrafish	D6-desaturase
Phosphorus metabolism	Zebrafish	Phytase
Vitamin C metabolism	Rainbow trout	L-gulono-gamma-lactone oxidase

* Changes in physical or chemical traits.

Source: Reprinted from Trends in Biotechnology, Vol. 24, Devlin RH, Sundstrom LF, Muir WM, Interface of biotechnology and ecology for environmental risk assessments of transgenic fish, p 89–97 (2006), with permission from Elsevier.

Several studies have shown that growth-enhanced transgenic fish have improved feed-conversion efficiency (Cook et al. 2000), resulting in economic and potential environmental benefits such as reduced feed waste and effluent from fish farms. Currently, no transgenic animal has been approved for food production in the United States, although that may change. A company called Aqua Bounty is currently awaiting regulatory review of its fish by the U.S. Food and Drug Administration (FDA).

Growth-enhanced salmon proposed

Atlantic salmon remains the most important farmed food fish in global trade. Salmon is a carnivorous fish, and aquaculturalists have been working to improve feed-conversion rates and efficiencies through selective breeding, and the inclusion of plant-based protein (soy, rapeseed oil and corn gluten) in feed formulations. As a consequence, feed input per fish has decreased to 44% of 1972 levels; likewise, current diets contain approximately half the content of fishmeal that they once did (Aerni 2004).

The first transgenic food animal to be submitted for regulatory approval in the United States was transgenic Atlantic salmon carrying a chinook salmon growth-hormone gene controlled by a cold-activated promoter from a third species, the ocean pout. The mature weight of these fish remains the same as for other farmed salmon, but their early growth rate increases by 400% to 600%, with a concomitant 25% decrease in feed input and a shortened time to market (Du et al. 1992) (see photos, page 129). Assuming a positive regulatory approval decision and consumer acceptance, the enhanced growth rate and feed efficiency of these transgenic salmon could increase salmon aqua-

ANR Communication Services

Transgenic fish are not currently produced for marketing purposes in the United States. *Above*, a consumer prepares salmon for cooking at home.

If transgenic fish are ill suited to an environment or are physically unable to survive outside of containment, then they may pose little risk to native ecosystems.

cultural productivity significantly, and would likely necessitate that salmon aquaculturists adopt the technology to remain competitive (Aerni 2004).

Risk factors of transgenic fish

Release or escape. The greatest science-based concerns associated with transgenic fish are those related to their inadvertent release or escape. Concerns range from interbreeding with native fish populations (Muir and Howard 2002) to ecosystem effects resulting from heightened competition for food and prey species. In principle, there is no difference between the types of concerns associated with the escape of genetically engineered fish and those related to the escape of fish that differ from native populations in some other way, such as a captively bred population (Lynch and O'Hely 2001). Ecological risk assessment requires an evaluation of the fitness of the transgenic fish relative to nontransgenic fish in the receiving population, to determine the probability that the transgene will spread into the native population. Fitness is defined as the genetic contribution by an individual's descendants to future generations of a population. It can be reduced to six net fitness components: juvenile viability, adult viability, age at sexual maturity, female fecundity (number of eggs), male fertility and mating success (Muir and Howard 2001).

The importance of accurately estimating each of the components of net fitness is demonstrated by the hazard exemplified by the "Trojan gene hypothesis." In this specific situation, the transgene confers enhanced mating success, but individuals possessing the transgene produce offspring with reduced juvenile viability. Depending upon the relative magnitude of the effects, an outcome associated with this particular set of circumstances can be the demographic destabilization and ultimate extinction of the native population (Muir and Howard 1999; Hedrick 2001). It is therefore important to evaluate each species and transgene combination on a case-by-case basis to estimate the components of net fitness relative to nontransgenic fish in the receiving population (Muir and Howard 2004).

Environmental factors. In addition to interbreeding, it is also important to consider the potential impact that environmental factors may have on the survival of transgenic and nontransgenic populations (i.e., genotype-by-environment interactions). A recent study of growth-enhanced transgenic and nontransgenic salmon found that transgenic salmon did not affect the growth of nontransgenic cohorts when food availability was high (daily feed ration equivalent to 7.5% of total fish biomass). However, the survival of both transgenic and nontransgenic cohorts was deleteriously affected when feed resources were limited to 0.75% of total fish biomass. The fast-growing transgenic salmon were found to dominate feed acquisition and exhibit strong agonistic and cannibalistic behavior toward their cohorts when there were inadequate feed resources (Devlin et al. 2004). Hunger and increased growth rates have been previously associated with agonistic behavior in nontransgenic salmonids, although in this experiment, unmodified populations receiving the reduced feed ration did not display such behavior.

The presence of transgenic fish will not a priori result in catastrophic results for native populations. If transgenic fish are ill suited to an environment or are physically unable to survive outside of containment, then they may pose little risk to native ecosystems. It is important to realize that neither the risks nor the benefits of transgenic fish are certain or universal. Both may vary according to a number of factors including the introduced gene, host species, containment strategy, species mobility, ability to become feral, relative fitness of the transgenic fish, receiving ecosystem, genotype-by-environmental interactions, and the stability of the receiving community. Regulators need to apply a scientifically sound, risk-based framework to assess the ecological risks involved with each transgene, species and

Kona Blue

The containment of transgenic fish will be a critical component of any commercialization strategy, to prevent interbreeding with wild, native fish. *Above*, a large-scale fish farming cage off Hawaii.

receiving ecosystem combination on a case-by-case basis.

Containment of transgenic fish

The commercialization of transgenic fish likely will be dependent upon the development of effective containment strategies. If transgenic fish are adequately contained, then they will pose little risk to native populations. The National Research Council (NRC 2004) recommended the simultaneous use of multiple containment strategies for transgenic fish, an approach that is consistent with the redundant fail-safe mechanisms used in other industries (e.g., the aircraft industry) where critical control must be maintained at all times.

Physical containment is an obvious first line of defense to prevent the escape of transgenic fish. Examples of such measures may include building facilities on land or removed from native populations, or ensuring that water chemistry (temperature, pH, salinity, concentrations of certain chemicals) is lethal to one or more life stages of the transgenic fish, such as treating effluent water to prevent the release of viable gametes or fry. Biological containment or bioconfinement approaches such as sterilization also are being developed (Fu et al. 2005; Maclean et al. 2002; Slanchev et al. 2005; Uzbekova et al. 2000).

The sterilization of transgenic fish would go a long way toward reducing the interbreeding risks associated with the escape of transgenic fish. Aqua Bounty plans to biologically contain its transgenic salmon by selling only triploid, all-female transgenic fish. Triploid fish, carrying three sets of chromosomes rather than the usual two, can be obtained by heat or pressure "shocking" the egg soon after fertilization to prevent the extrusion of the second polar body. Triploid fish are unable to produce viable eggs due to the fact that the third chromosome set interferes with the process of meiosis. Unfortunately, triploidy induction methods are not sufficiently effective to consistently ensure 100% sterility. The individual identification of fertile diploid larvae within batches of triploid larvae using particle analysis or flow cytometry of blood cells is an expensive proposition. Aqua Bounty plans to verify the sterility of every batch of transgenic salmon eggs using flow cytometry before they leave the hatchery.

Photos: Aqua Bounty Technologies (2002 and 2003)

Aqua Bounty has applied for federal approval to commercially produce a growth-enhanced, transgenic Atlantic salmon (*Salmo salar*). *Top,* at 18 months, the transgenic fish is clearly much larger than the same-age normal fish. *Above,* overall growth of the same generation of fish has evened out by 36 months.

Researchers are working on other genetic containment approaches including transgenic methods for the induction of sterility. A similar approach to genetically engineer sterility into transgenic plant seeds, dubbed the "terminator" technology, engendered a hostile response from certain environmental and farmer groups. In that case, concerns centered more on the effect that the technology would have on the farmer's right to save and replant seeds from their harvest, rather than on its potential to circumvent transgene escape. Whether the additional costs associated with containment will ultimately outweigh production savings or other benefits conferred by transgenes remains to be seen.

Global and U.S. regulations

While many countries have developed regulations for transgenic plant

varieties, few have similar regulations for transgenic animals. Government agencies in Cuba and China are currently reviewing proposals for the commercialization of genetically modified fish (Pew Initiative on Food and Biotechnology 2003). There are currently no international standards regarding the confinement of transgenic fish to prevent their potential release or escape into the environment.

In the United States, the use of transgenic fish is federally regulated under the Food, Drug and Cosmetics Act, with the FDA's Center for Veterinary Medicine (CVM) asserting primary jurisdiction over transgenic animals. Transgenic animals for production fall under CVM regulation as new animal drugs. Investigational applications are filed requesting approval for gene-based modifications, and following the provision of adequate safety data, the sponsor may request approval for these animals to be used for food or processing into animal feed components.

To date, no transgenic animals have been approved for use as human food, although the Aqua Bounty transgenic Atlantic salmon has been under regulatory review for more than 5 years. A limited number of transgenic animals have been approved for rendering into animal feed components (FDA 2006).

To coordinate multiple-agency federal oversight of transgenic organisms, the "Coordinated Framework" was adopted in 1986 to clarify the regulatory authority of the FDA, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA). These three agencies share jurisdiction over transgenic organisms through the Food, Drug, and Cosmetics Act (FFDCA), the Federal Insecticide, Fungicide, and Rodenticide and the Toxic Substances Control acts (EPA), and the Plant Pest Protection, the Plant Quarantine and the Virus, Serum, and Toxin acts (USDA). The Office of Science and Technology Policy published a package of regulatory case studies in 2001 in which the FDA indicated that it "intends to publish draft guidance on how the new animal drug provisions of the FFDCA pertain to transgenic animals, and on procedures by which companies developing transgenic animals can comply with those provisions." However, the government has issued no further guidance on the scope or implementation of such a policy.

John Stumbos

Above, **endangered native (nontransgenic) coho salmon are reared for a restoration effort at the Don Clausen Warm Springs Hatchery near the Russian River in Northern California. California regulations prohibit the importation or rearing of transgenic fish without a permit, in part due to concerns about risks to native fish populations.**

In addition to ensuring food safety, the FDA also evaluates environmental risks posed by transgenic animals as directed by the National Environmental Policy Act (NEPA). Under NEPA, federal agencies are obligated to cooperate with other involved federal agencies, and in the case of the Aqua Bounty transgenic salmon, this cooperation includes working with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service in the development of a scientifically based environmental risk assessment.

California weighs in

California was the first state to consider legislation to amend the Fish and Game Code to make it unlawful to import, transport, possess or release any live transgenic fish, or their roe, except under a permit. The bill, SB 1525, was introduced in 2002 and was supported by the Institute for Fisheries Resources, the Natural Resources Defense Council, The Ocean Conservancy, and a number of other groups, based on concerns that transgenic fish escaping into the wild might adversely affect the environment. SB 1525 did not pass and subsequently, its proponents sought another avenue to achieve their goals and petitioned the California Fish and Game Commission to prohibit the introduction of genetically altered fish into the state.

The Commission denied this petition, but then instructed the California Department of Fish and Game (DFG) to develop rules and regulations governing the use of transgenic fish in the state. A working group formed by DFG in cooperation with industry and environmental stakeholders — including the Natural Resources Defense Council, The Ocean Conservancy, UC and the California Aquaculture Association — worked collaboratively to establish these rules (California Code of Regulations 2003).

A permit is required under these rules to import, transport, possess, rear or conduct research on genetically modified fish in California. They must be kept in closed-water systems or ones that do not allow the inadvertent release of live fish, and access to facilities containing transgenic fish must be restricted. The Fish and Game Commission unanimously accepted these regulations in 2003, effectively adding transgenic aquatic animals to the state's list of restricted species. The regulations also require public comment, and the Commission must hold a

There are currently no international standards regarding the confinement of transgenic fish to prevent their potential release or escape into the environment.

public hearing for each permit application to ensure that any permit granted is in the public's best interest.

Additional California legislation related to transgenic fish was introduced in the 2003 legislative session as SB 245. This bill contains in part the following language: "In the waters of the Pacific Ocean that are regulated by this state, it is unlawful to spawn, incubate, or cultivate any species of finfish belonging to the family Salmonidae, transgenic fish species, or any exotic species of finfish." The bill exempts native California stocks that are propagated and cultured for release into ocean waters for the purpose of recovery, restoration or enhancement of California's native salmon and steelhead trout populations. This legislation passed both the California Assembly (50 to 26) and Senate (22 to 14), effectively precluding transgenic fish from coastal net-pen aquaculture up to 3 miles off California's shore.

What about GloFish?

In 2003, a transgenic zebra danio that produces a red fluorescent protein became commercially available in most U.S. pet shops. The zebra danio is a small aquarium species that has never survived outside captivity in the United States, despite repeated intentional and accidental releases. Federally, the FDA decided not to formally regulate GloFish. The rationale for this decision was explained in the following FDA statement: "Because tropical aquarium fish are not used for food purposes, they pose no threat to the food supply. There is no evidence that these genetically engineered zebra danio fish pose any more threat to the environment than their unmodified counterparts, which have long been widely sold in the United States. In the absence of a clear risk to the public health, the FDA finds no reason to regulate these particular fish."

This lack of formal regulation was seen by some as a "dangerous precedent" for the regulation of transgenic animals. Despite the FDA's decision not to regulate the commercial sale of GloFish, they are not currently available from pet stores in California as a result of the DFG regulations requiring a permit to import, transport, possess or rear genetically modified fish in onshore water systems.

Consumer acceptance will decide

In the near term, it is the marketplace more than the science that will decide the fate of new technologies and acceptability of certain risks. Food retailers and even farmers may be unwilling to stock the transgenic fish and risk having their market become the target of an organized anti-biotech campaign (Aerni 2004). Such a scenario occurred in Europe, where activist campaigns targeted retailers stocking labeled genetically engineered food products. Attempts to differentiate brands resulted in the removal of these products from supermarket shelves altogether (Kalaitzandonakes and Bijman 2003).

Despite strong public support for medical applications of genetic engineering, there is less public support for agricultural biotechnology. Market response and consumer behavior may differ markedly between affluent Western countries and those found in developing countries. Even if the FDA approves transgenic fish in the United States, it will likely be activist, food retailer and consumer responses in the marketplace that will ultimately decide whether transgenic food fish will sink or swim.

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What is the future of animal biotechnology?

by Alison L. Van Eenennaam

Animal biotechnology encompasses a broad range of techniques for the genetic improvement of domesticated animal species, although the term is increasingly associated with the more controversial technologies of cloning and genetic engineering. Despite the many potential applications of these two biotechnologies, no public or private entity has yet delivered a genetically engineered food-animal product to the global market, and the sale of milk or meat from cloned animals and their offspring is currently subject to a voluntary moratorium in the United States. The animal biotechnology industry faces a variety of scientific, regulatory, ethical and public acceptance issues. Effective and responsible communication among scientific, community, industry and government stakeholders will be required to reach a societal consensus on the acceptable uses of animal cloning and genetic engineering.

Above left, **Dot was cloned by UC Davis scientists from granulosa cells and,** ***above right,*** **Ditto from cumulus cells (both ovarian, follicular cell types) derived from,** ***top,*** **Daisy. Dot and Ditto were born in May 2003 and are normal, healthy cows. Both of the cloned cows have had calves, which also appear to be normal.**

AN article published in *California Agriculture* entitled "Genetic engineering and cloning may improve milk, livestock production" (Murray and Anderson 2000) detailed potential uses of these biotechnologies and optimistically concluded that "by midcentury most agricultural animals will be genetically engineered to be more efficient and healthier than current stock, producing healthy products for human consumption in an environmentally friendly system." While these technologies undoubtedly have the potential to deliver such benefits, no genetically engineered food animals are currently on the market, and the U.S. Food and Drug Administration (FDA) continues to call for a voluntary prohibition on the marketing of milk or meat from clones and their offspring. This review examines the scientific, regulatory, ethical and public acceptance issues faced by the animal biotechnology industry, and discusses the implications of the current climate on the future of animal biotechnology.

Biotechnology is defined as technology based on biology. From this definition it is obvious that livestock breeders have been practicing animal biotechnology for many years. For example, traditional selection techniques involve using observations about the physical attributes and biological characteristics of an animal to select the parents of the next generation. One needs only to look at the amazing variety of dog breeds to realize the influence that breeders can have on the appearance and characteristics of animals from a single species. Genetic improvement through selection, based on an increased understanding of population genetics and statistics, has

been an important contributor to dramatic advances in agricultural productivity (Dekkers and Hospital 2002).

Many different biotechnologies have been incorporated into livestock breeding programs to accelerate the rate of genetic improvement. These include artificial insemination (AI), sire-testing programs using data collected from thousands of offspring, synchronization of estrus, embryo transfer, cryopreservation of gametes and embryos, and DNA-based marker-assisted selection of genetically superior animals. Prior to their eventual widespread adoption, some of these new technologies were controversial, and their introduction met with some resistance (NRC 2002). Initially, artificial insemination was seen to be "against the laws of God, a repugnant practice that would lead to abnormal outcomes" (NRC 2002). Today this technology is widely used in agriculture, in addition to both veterinary and human medicine. Genetic improvements using traditional breeding techniques have not come without a price, and there are some health and welfare concerns associated with highly productive animals, such as gait abnormalities in broiler chickens and fertility problems in high-yielding dairy cattle. A comparable legacy has arisen from the selective breeding of domesticated dogs, which are now afflicted with more than 200 diseases of genetic origin.

Animal cloning

When most people hear the term animal biotechnology, they think of Dolly the sheep, the first mammal ever cloned or duplicated from an adult cell. The hype that surrounded Dolly in 1997 rapidly became entangled with the debate over human cloning, and the ensuing discussion failed to elaborate on the reasons for, or even differentiate between, cloning versus the genetic engineering of animals.

Cloning had actually been practiced for a long time before the appearance of Dolly. Splitting or bisecting embryos to make identical twins, a process in which the cells of a developing embryo are split in half and transferred into different recipient mothers, was introduced into livestock breeding programs in the 1980s. Identical twins are technically

GLOSSARY

Chromosome: A self-replicating DNA sequence found in the cell nucleus that bears a linear array of genes.

Cytoplasm: The cellular substance outside the nucleus in which the cell's organelles, such as mitochondria, are suspended.

Genetic engineering: The transfer of recombinant DNA sequences into the genome of a living organism.

Genome: The total DNA in a single cell, representing all of the genetic information of the organism. The normal human genome consists of 46 chromosomes, 23 from each parent.

Mitochondria: Components in cells that serve as primary energy sources for all cellular functions. Mitochondria have their own genome, present in only one copy, which does not recombine in reproduction.

Nucleus: A separate compartment in the cell that contains 6 feet of DNA packed into 23 pairs of chromosomes.

Recombinant DNA: The laboratory manipulation of DNA in which DNA, or fragments of DNA from different sources, are cut and recombined using enzymes.

A CLOSER LOOK

How animals are cloned and why problems sometimes occur

Cloning by **nuclear transfer** is a two-part process. First, scientists remove the nucleus from an egg, and then they fuse it with a somatic cell containing the nucleus and genetic material from another cell by the application of an electrical charge. The fused egg is then placed in a laboratory dish with the appropriate nutrients. Eventually the resulting embryo, which is a genetic copy of the animal that produced the somatic cell and not the egg, is transplanted into a surrogate mother.

The successful production of normal clones from differentiated somatic cells suggests that adult nuclear DNA retains the ability to direct the correct pattern of gene expression for embryogenesis. The process of resetting adult nuclear DNA to the embryonic pattern of gene expression is known as **reprogramming** and likely involves switching off certain genes and turning on others. Errors in reprogramming may lead to abnormalities in gene expression in cloned animals and affect the health and longevity of the animal.

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Epigenetic changes are visible in tortoiseshell female cats. Depending upon which X-chromosome becomes inactivated, some skin cells give rise to orange fur while others give rise to black fur.

Reprogramming involves changes at the **epigenetic** level. Epigenetic changes refer to alterations in gene expression resulting from modifications of the genome that do not include changes in the base sequence of DNA. Two key areas of epigenetic control are chromatin remodeling and DNA methylation. Epigenetic changes may also include **imprinting,** the switching off of maternal or paternal copies of certain genes.

With clones the reprogramming of somatic cell modifications is sometimes incomplete, leading to inappropriate patterns of DNA methylation, chromatin modification and **X-chromosome inactivation** in the developing clone. This can result in aberrant gene-expression patterns and correspondingly high rates of pregnancy loss, congenital abnormalities and postnatal mortality.

— A.L. Van Eenennaam

Alice Moyer

◀ **Rosie, *left*, born May 2002, was the first clone to be released from the UC Davis Veterinary Medicine Teaching Hospital. She died unexpectedly of a bacterial septicemia at 2 years of age. While it is unclear why Rosie became ill, there are some reports in the scientific literature of the premature death of cloned cattle.**

▶ **Leslie Lyons, *right*, associate professor in the UC Davis School of Veterinary Medicine, studies cats to investigate the genetic bases for inherited diseases in animals and humans. In 2002, Lyons confirmed that a cat born at Texas A&M University was the first cloned feline. Kiwi and Kashmir are purebred Oriental shorthair kittens that carry a lympho-sarcoma gene.**

▶▶ ***Far right*, scientists with UC Davis and Origen Therapeutics of Burlingame, Calif., have developed a system that uses primordial germ cells (PGCs) to pass on introduced traits to the next generation. The black chick among the white rooster's progeny shows that the injected PGCs successfully developed into sperm and that its genotype was passed on.**

clones, but the term is now more commonly used to refer to an individual that results from the transplantation of the DNA contained in a single somatic (non-egg) cell derived from an adult organism, into an enucleated oocyte (an egg that has had its own DNA removed). This process is called somatic cell nuclear transfer (SCNT) cloning, and it has been successfully performed in many livestock species (e.g., sheep, cattle, pigs and goats). From an animal breeding perspective, the importance of the SCNT procedure is that it allows the replication of adult animals with demonstrated superior performance attributes. Commercial companies providing fee-for-service cattle cloning have recently emerged, offering producers guaranteed-live cloned offspring for $10,000 to $20,000 per calf.

Agricultural uses. There are probably only a few prospective uses for cloned animals in commercial agricultural operations. They may provide a genetic insurance policy in the case of extremely valuable animals, or produce several identical sires in production environments where artificial insemination is not a feasible option. Theoretically, clones could also be used to reproduce a genotype that is particularly well suited to a given environment. The advantage of this approach is that a genotype that is proven to do especially well in a particular location could be maintained indefinitely, without the genetic shuffle that normally occurs every generation with conventional reproduction.

However, the disadvantage of this approach is that it freezes genetic progress toward desirable attributes, such as milk production or disease resistance, at one point in time. Since there is no genetic variability in a population of clones, within-herd selection no longer offers an opportunity for genetic improvement. Additionally, the lack of genetic variability could render the herd or flock vulnerable to a catastrophic disease outbreak or singularly ill-suited to changes that may occur in the environment.

Although clones carry exactly the same genetic information in their chromosomal DNA, they may still differ from each other, in much the same way that identical twins do not look or behave in exactly the same way. Clones do not share the same cytoplasmic inheritance of mitochondria from the donor egg, nor often the same gestational environment, since they are frequently borne and raised by different animals. In fact, a recent study showed that SCNT clones differ more from each other than do contemporary half-siblings (Lee et al. 2004).

Efficiency and problems. The cloning procedure is currently inefficient, with only 1% to 3% of the nucleated egg cells developing into live offspring. High rates of pregnancy loss have been observed at various times after placement of the eggs containing the adult cell nuclei into recipient animals. However, these problems are not seen universally in SCNT-cloned cattle, and there are reports of apparently healthy cloned cattle that have gone on to conceive and have healthy calves (Lanza et al. 2001; Pace et al. 2002).

Abnormalities have also been observed in cloned animals subsequent to birth, with frequencies that are at least partially dependent upon the type of tissue from which the transferred nucleus was derived. These abnormalities include defects in cardiovascular, musculoskeletal and neurological systems, as well as susceptibility to infections and digestive disorders. Many of these problems appear to result from incorrect reprogramming of the transferred nuclear DNA as it transitions from directing the cellular activities of a somatic cell to directing the complex developmental pathway required to develop into an entirely new embryo. Researchers have documented abnormal gene expression patterns in cloned offspring and errors in both imprinting and X-chromosome inactivation (Thibault 2003).

Food safety. The main underlying food-safety concern with SCNT clones is whether the nuclear reprogramming

Debbie Aldridge/UC Davis

Origen Therapeutics

that occurs during the cloning process has any influence on the composition of animal food products. There is no fundamental reason to suspect that animals derived via SCNT would produce novel toxins or allergens. Studies comparing the performance of SCNT clones and other types of dairy cattle clones to their full siblings found that there were no obvious differences in performance or milk composition (Takahashi and Ito 2004; Norman and Walsh 2004; Walsh et al. 2003; Tome et al. 2004; Tian et al. 2005).

The FDA Center for Veterinary Medicine has been developing a risk assessment to identify hazards and characterize food consumption risks that may result from cloning (Rudenko et al. 2004). Their report on livestock cloning states, "the current weight of evidence suggests that there are no biological reasons, either based on underlying scientific assumptions or empirical studies, to indicate that consumption of edible products from clones of cattle, pigs, sheep or goats poses a greater risk than consumption of those products from their nonclone counterparts" (FDA 2003). Despite these findings, the marketing of milk or meat from SCNT clones and their offspring remains subject to a voluntary prohibition. The FDA report states, "additional data on the health status of progeny, and composition of milk and meat from clones and their progeny, would serve to further increase the confidence in these conclusions." Several research groups are actively collecting these types of data.

Pets. Although the cloning of livestock has been ongoing for several years, the first cloned-to-order pet was sold in December 2004. "Little Nicky" was cloned from a deceased 17-year old cat named Nicky and cost its owner $50,000. This development fueled a debate over the need for such a product given that millions of cats are euthanized each year for want of homes, and the potential exploitation of grieving pet owners. This led to the introduction of California Assembly Bill 1428 to ban the retail sale of cloned and genetically modified pets. This bill failed to pass in the Assembly Business and Professions Committee in May 2005.

Genetic engineering

Although cloning is not genetic engineering per se, there is a logical connection between these two technologies. Genetic engineering involves the modification of characteristics of organisms using recombinant DNA techniques, with the specific intent of altering protein expression. A transgenic organism carries DNA originally derived from an organism other than its parents in its genomic DNA. Common examples of transgenic agricultural organisms are insect-resistant corn and cotton that has DNA from the soil microorganism *Bacillus thuringiensis* (Bt) incorporated into its genome (see page 116). To be passed on to the next generation, this novel transgenic DNA must be present in the organism's germ-line cells (egg or sperm). Microinjection of foreign DNA into newly fertilized eggs has been the predominant method used for the generation of transgenic livestock over the past 20 years. This technology is inefficient (3% to 5% of animals born carry the transgene) and results in random integration and variable expression levels of the target gene in the transgenic offspring.

Cloning enhances the efficiency of genetic engineering by offering the opportunity to produce 100% transgenic offspring from cell lines that are known to contain the transgene. This prospect stimulated the research that led to the development of SCNT cloning of animals, despite widespread media coverage about the highly controversial issue of human reproductive cloning. Cloning also offers the unique opportunity to produce animals from cells that have undergone precise, characterized modifications of the genome. This includes the disruption of specific endogenous genes, like those that encode the prion protein responsible for mad cow disease (bovine spongiform encephalopathy), or the allergenic proteins that cause the

James D. Murray, UC Davis animal science professor, and Artemis, the 7-year-old founder of a transgenic dairy goat herd at UC Davis. The goats express a lysozyme protein found in human breast milk into the udder, where it is secreted into the milk and confers increased antimicrobial activity.

rejection of animal organs in human xenotransplantation surgeries (where animal organs are transplanted into human patients) (Piedrahita and Mir 2004).

Agricultural applications. Genetic engineering was originally envisioned to have a multitude of agricultural applications. Recombinant bovine somatotropin (BST) derived from genetically engineered bacteria is one product of genetic engineering that is currently being used in animal agriculture. This protein, which increases milk production in lactating cows, is widely used throughout the U.S. dairy industry. Administering the protein rBST does not modify the DNA of the cow, and they do not become genetically engineered. BST was approved by the FDA in 1993 following extensive testing by numerous medical associations and scientific societies, which revealed no health or safety concerns for consumers (Bauman 1999).

The FDA is again the lead agency responsible for the regulation of genetically engineered food animals, and it plans to regulate transgenic animals under the new animal drug provisions of the Federal Food, Drug, and Cosmetic Act. To date only one company has publicly announced a request for FDA approval to market a genetically engineered food animal, a salmon that is capable of growing four to six times faster than standard salmon grown under the same conditions (see page 126).

At this point it seems unlikely that genetic engineering will find widespread use for improving most livestock production traits. Agriculturally relevant traits such as growth tend to be controlled by many genes, making it difficult to select or predict how the expression of one or two recombinant proteins might influence these complex performance traits. Additionally, traditional selection techniques achieve reliable and consistent rates of genetic improvement for most livestock species and do not require the investment, risk and time involved for the production and regulatory approval of genetically engineered organisms. Enhancing the nutritional attributes or safety of food animal products in ways that are not possible through traditional selection techniques, such as the production of hypoallergenic milk or low-cholesterol eggs, is one area where the genetic engineering of agricultural animals might provide unique opportunities for value-added products in the future.

Although clones carry exactly the same genetic information in their chromosomal DNA, they may still differ from each other, in much the same way as identical twins do not look or behave in exactly the same way.

Pharmaceutical/industrial uses. The most cost-effective application of genetic engineering in animals, at least in the short term, is likely to be the production of useful protein products. This involves applying genetic engineering to incorporate DNA sequences that encode desired proteins into the genome of animals. In contrast to the narrow profit margins for agricultural products, pharmaceutical or industrial proteins can be sold at a substantial markup. Transgenic proteins have been produced and secreted into the milk, blood, urine and semen of livestock, although to date most commercial systems favor the mammary gland.

One company, GTC Biotherapeutics, produces more than 60 different therapeutic proteins in the milk of both goats and cows. One of these proteins is antithrombin, a human plasma protein with anticoagulant and anti-inflammatory properties, which was planned for market launch in Europe in mid-2005. However, the Committee for Medicinal Products for Human Use of the European Medicines Agency issued a negative opinion on the Market Authorization Application for this product in March 2006. This decision was not related to the fact that its source was a transgenic animal, but rather to the determination that an insufficient number of surgical patients had been enrolled in a clinical trial to support approval of the product. GTC has exercised its right to have its application reexamined, and expects the reexamination to conclude in mid-2006.

Many human therapeutic proteins require modifications specific to animal cells in order to be effective, and genetically engineered animals could provide an important source of these protein drugs in the future. Another company, Nexia, has successfully produced spider silk proteins in the milk of genetically engineered goats. These proteins are purified from the milk and used to produce BioSteel, a strong fiber with medical, military and industrial applications. Other companies have not been commercially successful. The pioneering company PPL Therapeutics, which was responsible for the cloning of Dolly, experienced financial difficulties that resulted in the eventual sale of the company and its laboratories.

Environmental concerns. A report by the National Academy of Sciences stated that environmental issues were the greatest science-based concern facing the animal biotechnology industry (NRC 2002). The possibility that genetically engineered organisms, particularly fish and insects, could escape confinement and become feral was of high concern. The report also noted that the interbreeding of genetically engineered fish, especially those with increased fitness attributes (e.g., younger age at sexual maturity) could result in serious ecological consequences (Muir and Howard 1999, 2001, 2002).

The actual environmental risk posed by each species/transgene combination will depend upon a number of factors including the containment strategy(s), species mobility, ability to become feral, genotype-by-environmental interactions and stability of the receiving community. Likewise, food safety concerns related to transgenic animals will be similarly case-specific depending upon the attributes of the recombinant protein and whether it is intended to be a pharmaceutical, industrial or food protein. To encourage academic research in this area, the U.S. Department of Agriculture's (USDA) Biotechnology Risk Assessment Grants Program currently provides $3 million annually to support research designed to identify and develop appropriate management practices, and to minimize the physical and biological risks associated with genetically engineered animals, plants and microorganisms.

Animal welfare considerations

Animals are sentient, living creatures, and they are often treasured members of the family. As a result of varying personal belief systems, some people oppose the human use of animals for any purpose, while others have specific concerns about the impacts that genetic engineering and cloning may have on animal health and welfare. Some people find it particularly disturbing that industrial terminology such as "transgenic animal bioreactors" is used to describe genetically engineered animals producing human therapeutic or industrial proteins.

Animal cloning and transgenic methodologies themselves create some welfare concerns, not the least of which is the current inefficiency of the techniques, which results in the use of many more animals than would be needed if success rates were higher. Some of the reproductive manipulations (e.g., embryo transfer, superovulation) that are required for the production of genetically engineered animals and clones may cause pain or discomfort to the animal. However, these are not new or unique concerns specific to these biotechnologies; commercial livestock breeders have commonly employed such techniques for many years.

A problem that is often seen with bovine embryos cultured using in vitro embryo culture techniques (e.g., SCNT clones) is that the resultant calves tend to have high birth weights and long gestational periods. This phenomenon, known as large offspring syndrome, can result in calving difficulties and an increased rate of caesarian section for the dam. An animal welfare concern more specifically associated with genetically engineered animals is poorly controlled expression of the introduced gene. Various growth abnormalities have been noted in genetically engineered animals that are expressing a growth hormone transgene (Pursel et al. 1989; Devlin et al. 1995).

A more overriding concern is related not to the actual genetic manipulations themselves, but rather to animal welfare problems precipitated by breed-

The adoption of modern technologies is becoming increasingly important for the success of commercial livestock operations. *Above,* researchers at the UC Sierra Foothill Research and Extension Center use DNA tests and electronic animal identification equipment to individually track the parentage and performance of each animal and identify genetically superior breeding stock.

ing objectives. If biotechnology makes farm animal production more efficient, this may have the effect of worsening conditions that some already see as unacceptable, such as those found in concentrated animal-feeding operations. This concern is again not unique to genetic engineering, because any genetic selection program directed exclusively toward high production efficiency has the potential to cause welfare concerns for farm animals, irrespective of the techniques used to obtain that goal. Conversely, animal biotechnology might also be used to improve traits such as disease resistance, which could have the effect of decreasing animal suffering or mortality.

Although it is possible that genetic engineering will be used to increase agricultural productivity, in the short term it seems more likely that this technique will be used for biomedical applications. In this case, genetic manipulation is not intended to cause changes that have physiologic effects on the animals themselves and generally raises fewer potential animal welfare concerns (NRC 2002). There are still some unique concerns such as the premature lactational shutdown that has been observed in some animals expressing recombinant proteins in their mammary gland (Shamay et al. 1992). Additionally, the specific pathogen-free housing requirements for animals intended to produce human therapeutics or organs for human transplantation may compromise the behavioral needs of the animal.

Ethical concerns

One genetically engineered animal, a red fluorescent zebrafish called GloFish, is commercially available in the United States (see page 126). Federally, the FDA decided not to regulate GloFish on the basis that tropical fish pose no threat to the food supply and the fact that there is no evidence that these genetically engineered zebrafish pose any greater threat to the environment than their widely sold, unmodified counterparts. However, California's Fish and Game Commission decided to prevent the sale of these transgenic zebrafish to aquarium hobbyists in the state. This decision was not founded on science-based evidence of environmental risk — since zebrafish is a tropical species that is not sufficiently cold tolerant to reproduce in California waters — but rather on ethical grounds. In reaching this decision, one of the commissioners stated that he did not think it was right to produce a new genetically engineered organism "just to be a pet."

This brings up a unique aspect of genetic engineering as it relates to animals, and that is the special place that animals hold in our society. It is doubtful that a genetically modified blue rose would be prohibited based on the fact it was just going to be in a floral arrangement. There are two central ethical concerns associated with the genetic engineering of animals. The first has to do with breaching species barriers or "playing God." Proponents of this view suggest that life should not be regarded solely as if it were a chemical product subject to genetic alteration and patentable for economic benefit. The second major ethical concern is that the genetic engineering of animals interferes with the integrity or "telos" of the animal. Telos is defined as "the set of needs and interests which are genetically based, and environmentally expressed, and which collectively constitute or define the form of life or way of living exhibited by that animal, and whose fulfillment or thwarting matter to that animal" (Holland and Johnson 1998).

Scientists might argue that science does not make value or moral judgments, and therefore ethics is not scientifically relevant. The scientific process places a high value on controlled experiments as a way to obtain understanding. Potential, and maybe even fanciful concerns, do not mesh well with a process that focuses on what can be measured, analyzed and quantified. This proclivity to value that which is verifiable and subject to experimental manipulation may be at odds with the values of other groups in society. Given that ethics are difficult to integrate into the scientific process, it is perhaps not surprising that scientists often fail to articulate the ethical issues occasioned by their work, allowing that discussion to be carried out in the press or by those with a particular axe to grind. To help address this disconnect, graduate students at many universities are now required to attend ethics courses in addition to their core curriculum.

Public perceptions

In a survey conducted in 2005, only 6% of respondents indicated they had heard or read a lot about applying the science of biotechnology to animals, and 45% indicated they had heard "nothing at all" about the topic (IFIC 2005). A 2003 public knowledge study by Rutgers University found that 51% of respondents associated the word "cloning" with the terms "genetic engineering" and "genetic modification," which is perhaps not surprising given that these terms are not used consistently in the media. Despite finding that the majority of people surveyed admitted to knowing "very little" (55%) or "nothing at all" (22%) about biotechnology, the Rutgers study also found that the majority of those interviewed disapproved of animal-based "genetically modified" foods (Hallman et al. 2003). As a point of reference, half of the respondents in a 2002 study by the same group had never heard about traditional livestock crossbreeding schemes, and this widely used breeding approach received only a 31% acceptance rating; at the same time, 50% of the respondents indicated that they considered the crossbreeding of animals to be morally wrong (Schilling et al. 2002).

The Rutgers studies showed that for many Americans, biotechnology remains an abstract and unfamiliar concept that, in the absence of other information or knowledge, evokes negative reactions. Many of the respondents who initially disapproved of the genetic modification of animals in an abstract sense later indicated that they approved when presented with specific examples, suggesting that opinions about genetic modification are malleable when additional information is presented. This is perhaps not surprising given the fact that most people do not consider themselves informed about biotechnology and related topics, and they generally lack knowledge about the process of livestock and food production in the United States (Hallman et al. 2003). Many people change their attitudes when presented with information on why the technology is being used, and if they view the potential benefits as important.

Communicating risks and benefits

Although to date the only genetically engineered animal available on the U.S. market (but not in California) is a glowing red aquarium fish, this technology has the potential to address other more vital societal interests. Given that the term "animal biotechnology" elicits a negative public reaction in the absence of any other information, scientists have an obligation to engage in the public discourse by articulating the science-based risks and benefits of their research, in addition to the ethical issues occasioned by their work. Polarizing the issue of genetic engineering of animals into "all is permitted" or "nothing is permitted" prevents rational social progress on the issue. Effective and responsible communication among scientific, community, industry and government stakeholders is essential to reach a societal consensus on the acceptable levels of risk for specific products of animal biotechnology, and to determine which set of values will ultimately be applied to decide the acceptable uses of animal biotechnology.

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RESEARCH ARTICLE

Conservation tillage production systems compared in San Joaquin Valley cotton

by Jeffrey P. Mitchell, Daniel S. Munk, Bob Prys, Karen K. Klonsky, Jon F. Wroble *and* Richard L. De Moura

Tillage operations, including preplant soil preparation, in-season weed control and postharvest stalk management, can account for 25% or more of overall cotton production costs. These operations reduce soil organic matter and contribute to air pollution. Conservation tillage practices similar to those used successfully elsewhere in the Cotton Belt may be a viable means for increasing profitability and improving soil in San Joaquin Valley cotton fields. In a comparison of reduced-tillage production methods, conservation tillage planting and stalk-management systems had yields comparable to those of standard tillage practices in two back-to-back cotton crops in Riverdale, Calif. These reduced-till systems decreased the number of tractor operations by 41% to 53%, fuel use by 48% to 62%, and overall production costs by 14% to 18%.

Conservation tillage seeks to reduce the number of times growers must do tillage "passes" through their fields with heavy equipment. The TerraTill parabolic shank subsoiler is used for the postharvest management of cotton stalks, to control pink bollworm.

Since the California Aqueduct opened as part of the Central Valley Improvement Project in 1963, cotton has been an important crop throughout much of the San Joaquin Valley. Cotton (*Gossypium hirsutum*) is routinely produced in rotation with other annual row crops including processing tomatoes, onions, garlic and melons, and field crops such as wheat and barley, particularly in the San Joaquin Valley's west side. Between 1992 and 2002, more than 750,000 acres of cotton on average were harvested annually from Merced County to the north through Kern County to the south. During this same period, however, production costs for cotton in some areas and years eclipsed the value of lint and seed, even with the federal support payments provided to producers. Improving profitability has become a clear mandate for sustained cotton production in the San Joaquin Valley.

An important management variable that producers can directly control is tillage. Preplant soil preparation, in-season weed control and postharvest stalk management are tillage-related operations in cotton production that can account for 25% or more of overall cotton-production costs (Carter 1996). These tillage operations represent not only high energy, equipment and labor costs, but they also reduce soil organic matter (Reicosky and Lindstrom 1995), and contribute air pollutants such as oxides of nitrogen and fine particulate dust (Baker et al. 2002). The adoption of conservation tillage (CT), or reduced-tillage practices similar to those used successfully elsewhere in the Cotton Belt, may be a viable means for increasing profitability and improving the soil in San Joaquin Valley cotton fields.

"Conservation tillage" typically refers to a cropping system that leaves at least one-third of the soil covered with crop residue after planting. "Reduced tillage" systems have 15% to 30% residue on the soil surface after planting, while "no-till" systems have high crop residue content throughout the cropping season accompanied by little or no soil tillage throughout the year. On a nationwide basis, about 3.27 million acres (29%) of cotton acreage used conservation tillage or reduced-tillage practices in 2002 (Towery 2002). From 1992 to 2002, no-till cotton acreage increased 740% in the United States, led by Georgia, North Carolina, Mississippi, Tennessee and Alabama (Towery 2002).

The need to control pink bollworm through tillage and crop residue management, the lack of inexpensive alternatives for preplant weed control and unfamiliarity with conservation tillage production systems are obstacles that have prevented the greater adoption of

TABLE 1. Preplant and postharvest operations used in tillage-systems evaluation at Borba Farms, Riverdale, Calif., 2001–2002

Systems evaluated*†						
1: Standard	2: NT/chop	3: NT	4: RT/chop	5: RT	6: ST/chop	7: ST
Chop cover crop	Chop cover crop	No-till plant cotton with JD 1730 planter	Chop cover crop	Ridge-till plant cotton with Buffalo 8000 planter	Chop cover crop	Strip-till seed bed
Disk	No-till plant cotton with JD 1730 planter	Apply glyphosate over the top	Ridge-till plant cotton with Buffalo 8000 planter	Apply glyphosate over the top	Strip-till seed bed	Plant cotton with JD 1730 planter
Disk	Apply glyphosate over the top	Cultivate	Apply glyphosate over the top	Cultivate	Plant cotton with JD 1730 planter	Apply glyphosate over the top
Chisel	Cultivate	Harvest cotton	Cultivate	Harvest cotton	Apply glyphosate over the top	Cultivate
Disk	Harvest cotton	Shred stalks	Harvest cotton	Shred stalks	Cultivate	Harvest cotton
List beds	Shred stalks	Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds	Shred stalks	Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds	Harvest cotton	Shred stalks
Plant cotton with JD 1730 planter	Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds		Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds		Shred stalks	Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds
Ring roll					Root-pull stalks and/or TerraTill subsoiler with rotary harrows to relist beds	
Apply glyphosate over the top						
Cultivate						
Harvest cotton						
Shred stalks						
Disk						
Disk						
Subsoil/relist beds						

* NT/chop = no-till with cover crop chopped; NT = no-till; RT/chop = ridge-till with cover crop chopped; RT = ridge-till; ST/chop = strip-till with cover crop chopped; ST = strip-till.

† The herbicide glyphosate was initially applied in all systems to kill the cover crop.

reduced tillage in San Joaquin Valley cotton (Carter 1996). While these are still formidable issues, recent innovations have made the prospect of developing reduced-tillage options for California cotton achievable. These include the introduction of reduced-pass rebedding equipment that facilitates pink bollworm plowdown compliance, the advent of various herbicide-resistant cotton varieties, and the availability of high surface-residue cultivators and planters.

Farm tillage study

To evaluate and refine possible conservation tillage systems for cotton, we initiated a study with Borba Farms in Riverdale, Calif., in fall 2000. Borba Farms is a 13,000-acre diversified farm, located in south-central Fresno County, which produces a variety of crops including cotton, processing tomatoes, wheat, alfalfa, sugar beets, garlic and onions. Three replications of seven cotton planting and postharvest stalk-management systems were set out in 30-inch beds across a 12-acre field (table 1). A standard crop-management approach (system 1) employing typical, currently used methods of planting and cotton stalk management was established as a reference or control plot.

Prior to each of the two cotton crops in the study, a winter cover crop of barley (*Hordeum vulgare*) was grown across the entire experimental field to add organic matter to the soil and improve tilth. The soil in this field is a Grangeville fine sandy loam, which is a coarser-textured soil than much of the cotton production land farther west in Fresno, Merced and Kings counties. Borba Farms routinely uses small-grain cover crops as a means to improve overall soil quality and reduce crop stand losses caused by blowing sands or inadequate bed moisture in their coarser-texture fields. These cover crops were seeded on Nov. 1, 2000, and Nov. 15, 2001. After about 3 months they were sprayed with the herbicide glyphosate and then disked, prior to reestablishing planting beds in the standard tillage system in late March of the following springs.

Three planting systems were evaluated alongside a conventional or standard tillage system: no-till, ridge-till and strip-till. In the no-till system, the only tillage is the soil disturbance in a narrow slot created by coulters or seed openers at planting. Ridge-till is a reduced-disturbance planting system in which crops are planted and grown on ridges (the equivalent of "peaked" beds) formed during the previous growing season and maintained with shallow in-season cultivation equipment. In the ridge-till system, planters sweep away or sheer off residues and soil in the seed line, but do not disturb much of the soil surface between rows. In strip-till, coulters cut residues ahead of subsoiling shanks, which loosen the soil from a few to as many as 14 inches ahead of a planter.

***Left to right,* no-till, ridge-till and strip-till planting into barley cover crops at Borba Farms, in Riverdale, Calif. These alternative tillage systems were compared to conventional tillage in cotton.**

In each of these conservation tillage systems, only a small percentage of the soil surface is disturbed, unlike the "broadcast" tillage, or land preparation operations that are typically used in conventional tillage systems. Prior to planting, the cover crops in all three tillage systems were either sprayed with the herbicide glyphosate and chopped with a flail mower a week later (systems 2, 4 and 6) or only sprayed with glyphosate (systems 3, 5 and 7). A six-row, 30-inch John Deere 1730 (Moline, Ill.) planter was used in systems 1, 2, 3, 6 and 7, and a Buffalo 8000 Ridge-Till Planter (Fleischer, Neb.) was used in systems 4 and 5. Each planter was calibrated to plant 58,000 seeds per acre with an expectation for standard final plant populations of at least 40,000 plants per acre. Riata, a conventional California glyphosate-tolerant (Roundup Ready) cotton variety, was used in both years of the study in all planting systems.

A global positioning system (GPS) tractor guidance system was used for the subsequent cotton planting in 2002 to maintain the integrity of the tillage plots. Following harvest of the 2001 and 2002 crops, cotton stalks in system 1 were shredded using a flail mower. These control plots were then disked twice and ripped to a depth of about 18 inches, then planting beds were re-established using a TerraTill (Bigham Brothers, Lubbock, Texas) subsoiler shank fitted with bed-shaper shovels. Postharvest stalk management in each of the other systems consisted of shredding, root-pulling with a Sundance implement (Coolidge, Ariz.) and relisting beds (creating beds and furrows in a flat field) using the TerraTill parabolic shank subsoiler without shovels in 2001. In 2002, after the stalks were shredded, the beds were subsoiled and listed using disc-blade cultivator tools mounted at the back of the TerraTill implement. The conservation tillage systems differed from the standard tillage system in terms of presence of a cover crop, plus both preplant and postharvest tillage operations (table 1). The tillage systems were managed from the general principle of reducing tillage to the greatest extent possible while using generally available equipment and maintaining yields at desired levels.

Cotton stand establishment was monitored at about 1 month following planting each year by counting the number of emerged seedlings along 100-foot lengths in each plot. Standard cotton-plant mapping procedures were used during each season to characterize crop growth and development. Yield was determined by machine harvesting and weighing lint and seed from the center four or eight rows in each six- or 12-row plot, respectively. Six-pound harvest samples from each plot were ginned at the UC Shafter Cotton Field Station. Gin turnout, or the lint percentage of the total sample by weight, was determined. We maintained records of all field operations, including implement width and tractor horsepower.

Crop productivity

Cotton plant populations generally adequate for optimal yields were achieved by each planting system in both years of our study, with the exception of ridge-till (systems 4 and 5) in 2002, when we set the seeding depth too low. Our test of the ability of these conservation tillage planting systems to achieve adequate stands in herbicide-sprayed and chopped cover crop (systems 2, 4 and 6) or herbicide-sprayed cover crop (systems 3, 5 and 7) was only conducted in 2001 due to the fact that the cover crop was chopped in all systems in 2002.

However, a reduction in plant stands, as evidenced by the higher incidence of 3-foot skips (space between plants), was seen in both the no-till (system 2) and ridge-till (system 4) planting systems in the sprayed-only cover crop relative to the sprayed and chopped cover crop in 2002 (table 2). The evaluation of planted seed in the ridge-till plots indicated that average seed placement was about 4 to 5 inches deep. Seed germination and soil moisture were adequate to achieve an acceptable plant population, but the seedlings had difficulty emerging from these depths. Because stand establishment was generally adequate except in the 2002 ridge-till system, this single-year evaluation of cover-crop management approaches requires additional testing to determine the relative benefits of herbicide spraying alone, or herbicide spraying in conjunction with chopping

TABLE 2. Average number of plants per acre for cotton tillage-system evaluation at Borba Farms, Riverdale, Calif., 2001 and 2002, and percentage of field with plant skips greater than 3 ft. based on 100 ft. of sampled row, 2002

Cover crop / tillage system*	2001	2002	2002 (≥ 3 ft. plant skips)
	Avg. no. plants/acre		*% field*
1: Standard	34,200	44,500	1.3
2: NT/chop	41,200	45,500	8.6
3: NT	34,500	42,600	10.6
4: RT/chop	39,500	21,200	32.0
5: RT	34,500	19,900	23.5
6: ST/chop	39,000	38,200	13.8
7: ST	46,800	39,800	11.3

* NT/chop = no-till with cover crop chopped; NT = no-till; RT/chop = ridge-till with cover crop chopped; RT = ridge-till; ST/chop = strip-till with cover crop chopped; ST = strip-till.

TABLE 3. In-season plant height and fruiting nodes, June 11; height, fruiting nodes and nodes above white flower (NAWF) on July 17, 2002, Borba Farms, Riverside, Calif.

	Cover crop/tillage system*						
	1: Standard	2: NT/chop	3: NT	4: RT/chop	5: RT	6: ST/Chop	7: ST
June 11							
Height (inches)	7.4a †	5.8bc	5.8bc	5.4c	5.4c	5.8bc	6.5b
Fruiting nodes	2.6a	1.6b	1.5bc	1.1bc	0.6c	1.1bc	1.8b
July 17							
Height (inches)	35.3cd	34.3e	38.8ab	35.6cd	35.8cd	39.7a	37.0bc
Fruiting nodes	11.2c	11.2c	11.8bc	12.8a	11.6c	12.5ab	11.6c
NAWF	4.2e	8.0b	5.0d	9.0a	6.7c	7.8b	6.3c

* NT/chop = no-till with cover crop chopped; NT = no-till; RT/chop = ridge-till with cover crop chopped; RT = ridge-till; ST/chop = strip-till with cover crop chopped; ST = strip-till.

† Means followed by different letters differ significantly ($P < 0.05$).

prior to conservation tillage seeding. These follow-up studies are under way.

Irrigation "checks" or borders divided the study field, and water was applied using open valves. Each check was about 200 feet long. No difficulties were observed in terms of advancing water down these checks in any particular tillage treatment.

In-season plant monitoring data assisted us in identifying contrasting cotton growth and development patterns between tillage treatments that affected crop performance. Differences in surface residue cover, for instance, can modify the crop microclimate by changing the reflected surface radiation and soil sensible heat balance. Cover-crop residues remaining on the soil surface are highly reflective and often result in lower surface soil temperatures, thereby reducing plant growth (Van Doren and Allmaras 1978), and can result in reduced early-season plant growth. About 2,183 pounds of cover-crop residue (dry weight) in 2000 and 1,346 pounds in 2001 were present on the soil surface at the time of planting. Plant mapping measurements conducted in June found shorter plants with fewer fruiting branches for the tillage treatments having high surface-residue content (table 3). The conventional tillage treatment had produced one to two additional fruiting branches by June 11, 2002. Generally, however, differences in plant height and fruiting-node number were minimal by mid-July.

Mid- and late-season plant monitoring also included the evaluation of nodes above white flower (NAWF), an indicator of crop maturity or earliness. The conventional tillage treatment had consistently lower NAWF values, indicating that conventional tillage encouraged crop earliness and alternative tillage delayed crop maturity. In locations where crop earliness is favorable, this may be a drawback to the use of alternative tillage practices.

Yield data from this study reveals important management strategies that may be used to further develop and optimize conservation tillage cotton production systems in the San Joaquin Valley. In both years, strip-till prior to planting — a more aggressive seedbed preparation practice — had the most consistent yields, averaging 1,307 pounds of lint per acre in 2001 and 1,251 pounds per acre in 2002. In the light or sandy soil at this experimental site, strip tillage provided seedbed conditions that were fully adequate for crop establishment, growth and development.

In 2001, the two strip-till systems (systems 6 and 7) yielded more cotton lint than the standard tillage control (system 1). System 3, no-till planting into standing herbicide-killed cover-crop residue, had the lowest yields of the conservation tillage systems in 2001. In 2002, the decreased plant populations in the two ridge-till systems corresponded to significantly lower lint yields relative to the standard-till system and the other conservation tillage systems. In that year, an extra pass with a "ring roller" implement was made in system 1. We believe this operation improved seed contact with moist soil at planting, which resulted in improved seedling emergence and early-season vigor.

Postharvest stalk management

Effective control of pink bollworm (*Pectinophora gossypiella*), a pest that damages cotton bolls and has cost the U.S. cotton industry billions of dollars over the years, has been a long-standing priority of San Joaquin Valley cotton producers. A major strategy for pink bollworm control, which has been highly successful for more than 30 years in the San Joaquin Valley, is an IPM approach largely based on a pest-monitoring program and the controlled use of a biological control method. Components of the system include a minimum "host-free" period in which no cotton plants are available as hosts to the pest. This minimum period is from mid- to late December (last date for cutting plant stems from the roots and incorporating plant residue) through

At Borba Farms, cover crops were managed several different ways prior to cotton planting. *Left center,* herbicides were sprayed on the cover crop; *right,* the cover crop was sprayed and chopped; *far left,* the cover crop was disked in.

March 10 (earliest allowed planting date in the San Joaquin Valley). Other parts of the pink bollworm control program include monitoring pink bollworm adults in pheromone-baited traps placed throughout California cotton fields, followed by the targeted release of sterile moths to disrupt normal mating.

In this study, we evaluated two systems for reduced-pass cotton stalk management. At the end of the 2001 crop, we used a sequence of operations that involved shredding, root-pulling and subsoiling using a TerraTill "bent leg" shank. This series of operations was effective in killing cotton plants throughout each of the conservation tillage systems and was given a provisional clearance by the Kings County agricultural commissioner. Following the 2002 crop, the same series of operations was repeated, except that the TerraTill was fitted with sets of double rotary disc harrows, known as "Go Devils," mounted behind to throw up beds in a single-pass operation. This sequence of postharvest operations was also highly successful in killing cotton plants and was deemed in compliance with pink bollworm stalk-management requirements by the local agricultural commissioner.

TABLE 4. Cotton yields for tillage systems, Borba Farms, Riverdale, Calif., 2001 and 2002

Cover crop/ tillage system*	2001	2002
	lb. lint/acre	
1: Standard	993c †	1,311a
2: NT/chop	1,183abc	1,258a
3: NT	1,081bc	1,215a
4: RT/chop	1,292ab	709b
5: RT	1,229abc	809b
6: ST/chop	1,352a	1,278a
7: ST	1,262ab	1,223a

* NT/chop = no-till with cover crop chopped; NT = no-till; RT/chop = ridge-till with cover crop chopped; RT = ridge-till; ST/chop = strip-till with cover crop chopped; ST = strip-till.

† Means followed by different letters differ significantly ($P < 0.05$).

Practical lessons

This study revealed the short-term feasibility of using conservation tillage planting and stalk-management systems to produce cotton in California's San Joaquin Valley, with adequate yield, quality and pest management outcomes for this site's production standards. The study was conducted in a commercial production field and represents a reasonable scale of operation for current cotton production systems in the San Joaquin Valley. Lint yields in all of the treatments equaled average Fresno County yields in 2001, but were about 150 pounds per acre below average in 2002. Yields of each of the alternative tillage systems equaled or exceeded the yield of the standard tillage system in the first year, while yields in the 2002 standard tillage system were numerically, though not statistically, higher than the alternative tillage systems (table 4). The ridge-till systems had significantly lower yields in 2002, largely

TABLE 5. Cover crop and tillage-system tractor operations, estimated fuel use and production costs per acre

	Cover crop/tillage system*						
	1: Standard	2: NT/chop	3: NT	4: RT/chop	5: RT	6: ST/chop	7: ST
Times over field	17	9	8	9	8	10	9
Gallons of fuel	19.5	8.5	7.5	8.5	7.5	10.2	9.2
Total operating costs	$237	$199	$195	$199	$195	$204	$200

* NT/chop = no-till with cover crop chopped; NT = no-till; RT/chop = ridge-till with cover crop chopped; RT = ridge-till; ST/chop = strip-till with cover crop chopped; ST = strip-till.

In this study, lint yields were comparable to the regional average for all treatments during the first year, but yields in the alternative tillage systems were somewhat below average in the second year. However, fuel use in the alternative systems was reduced 48% to 62%, and production costs were down 14% to 18%. *Left,* cotton harvest.

due to the problems encountered with reduced plant stands. While these alternative tillage systems all delayed crop maturity (table 3) and reduced the earliness of fruit-set, there were adequate heat units during the 2002 season to compensate for any differences with no significant influence on yield.

Yield is an important determinant of farm profitability, but reducing inputs and operational costs are other ways to affect a farm's bottom line. The conservation tillage systems evaluated in this study reduced the number of tractor operations used to produce a cotton crop by 41% to 53%, depending on the system (table 5). This corresponded to an estimated reduction in fuel use of 48% to 62%, and a reduction in overall production costs of 14% to 18%. By extrapolation and based on companion studies we have recently completed, we would expect that a corresponding decrease in direct particulate-matter emissions would be achieved by the conservation tillage alternatives relative to the conventional tillage system.

Converting to reduced-till production alternatives, however, requires a number of significant operational changes, and each of these requires an upfront investment in additional equipment, time and management in order to be successful. The operating agronomist at Borba Farms committed considerable time and thought to each of the management issues he faced during the course of this work. His behind-the-scenes "trial and error" innovation is not borne out in any of the cost estimates we have presented here. This component was indispensable for the success of this study.

For major changes to be implemented in overall agricultural production systems such as those we evaluated, "attitude" is often cited as a prerequisite for success (Bradley 2002). Developing an attitude for change may become increasingly popular if more successful examples of conservation tillage production systems can be demonstrated (Mitchell et al. 2002). Large-scale research and demonstration efforts at this farm site have provided promising results in terms of yield responses and the ability to reduce tillage passes and costs. Collectively, the researchers and growers demonstrated that specific variations of reduced-tillage systems can be successfully used for a 2-year cotton-cotton rotation, with yields similar to conventional tillage and significant reductions in production and labor costs. Further tests are needed to help answer questions about how soil texture, crop rotation, and residue type and amount influence yield responses and alternative tillage choices.

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Conservation tillage and cover cropping influence soil properties in San Joaquin Valley cotton-tomato crop

by Jessica J. Veenstra, William R. Horwath, Jeffrey P. Mitchell *and* Daniel S. Munk

Following 4 years of a cotton-tomato rotation on the west side of the San Joaquin Valley, conservation tillage and cover crops altered physical and chemical properties of soil. In conservation tillage systems, bulk density decreased and available concentrations of nitrate and phosphorus increased. In contrast, the conservation tillage system redistributed potassium to the surface of the soil, lost organic matter and increased salt concentrations, all potentially detrimental to plant growth. Cover cropping, on the other hand, increased soil organic matter regardless of the tillage treatment, and increased potassium concentrations. By cover cropping, farmers in this region may improve their soil quality; however, the benefits of conservation tillage to soil quality are fewer and will require more research to determine long-term effects.

William Horwath, UC Davis professor of land, air and water resources, and Jessica Veenstra, graduate student at Iowa State University, examine cotton plants for a 4-year study of the effects of conservation tillage — with and without cover crops — on soil quality.

Intensive tillage practices are contributing to declining air, water and soil quality in California's Central Valley. Reducing soil disturbance by implementing conservation tillage practices may improve this situation. Conservation tillage is defined as any tillage system that leaves 30% or more of the soil surface covered with crop residue after planting. Conservation tillage reduces dust emissions from agricultural fields by decreasing the frequency and intensity of tillage operations. Limiting soil disturbance has been shown to improve the soil's tilth and fertility, increase water infiltration, increase organic matter storage and reduce erosion (Holland 2004; Uri et al. 1998). However, these benefits may be dependent upon cropping system, climate and soil type, so it is important to determine if conservation tillage will provide the same benefits to California agriculture, with its diversity of cropping systems, warm, semiarid climate and variety of soil types.

While reduced-tillage systems are common in the Midwest and South, conservation tillage is seldom practiced in California. Growers perceive its adoption to be difficult because tillage aids weed and disease management, loosens compacted soils and allows for the efficient distribution of irrigation water in furrows. California growers consider tillage necessary to maintain the high yields typical of the state's field and row-crop systems. On the other hand, conventional tillage operations consume considerable energy and increase equipment and labor needs, so there may be an economic benefit to converting to conservation tillage. Conservation tillage crop production practices may help reduce the environmental impacts and production costs of California agriculture.

Role of soil organic matter

Frequent tillage can reduce the amount of organic matter in soil, an important aspect of its quality. Soil organic matter refers to all of the organic material in soils, including decaying plant material, soil microbes and humified substances. Organic matter improves the biological, chemical and physical properties of soil and provides readily available nutrients for plant and microbial uptake. Properly managed soil organic matter can increase nutrient availability to plants, which may allow farmers to reduce fertilizer use (Reeves 1997).

Through interactions with minerals, organic matter can improve the physical properties of soil, including aggregate stability, aeration, water-holding capacity and water infiltration. By disrupting soil aggregates, intensive tillage exposes protected organic matter to increased microbial activity, which leads to its loss as carbon dioxide. In contrast, by decreasing soil disturbance, conservation tillage

One challenge of growing cover crops with conservation tillage is managing the residue to avoid complications with furrow irrigation.

systems have the potential to accumulate organic matter in some geographic regions. In other regions, conservation tillage redistributes organic matter to the soil surface while decreasing organic matter in the subsurface, depending on soil type and climate.

Adding organic matter as a cover crop can also benefit crop growth and improve soil quality. Cover crops can be legumes such as vetches or clovers, which fix nitrogen, or nonlegumes such as ryegrass or sudangrass, which immobilize nitrogen prone to leaching. Legume cover crops can add up to 89 pounds nitrogen per acre (100 kilograms nitrogen per hectare) through biological nitrogen fixation (Poudel et al. 2001). Cereal and grass cover crops can act as a "catch crop" to tie up nitrates during winter rains, preventing them from leaching into ground or surface waters. Mixtures of legume and cereal cover crops can perform both functions.

Cover crops also increase organic matter by increasing the amount of biomass added to the soil. The additional biomass of cover crops can be incorporated into the soil as a green manure in standard tillage systems or left on the surface as mulch in conservation tillage systems. When left on the surface, cover crop residues have been shown to effectively control weeds, reduce soil erosion and conserve soil moisture by reducing evaporation (Hartwig and Ammon 2002; Lu et al. 2000). In California, the use of conservation tillage and cover cropping together is especially uncommon in field and row-crop systems.

Evaluating tillage practices

We evaluated the effects of conservation tillage and cover cropping on physical and chemical soil properties in a tomato-cotton rotation typical of

TABLE 1. Tillage practices for each treatment*

	CTCC	CTNO	STCC	STNO
No. tractor passes	13	12	21	18
Tillage after tomato	Disk twice Ripping Level List beds		None	
Tillage after cotton	*All of the above plus:* Shred cotton Undercut cotton Incorporate/shape beds Cultivate Roll beds		Clean furrows Shredder/bedder Cultivate	

* CTCC = conservation tillage, cover crop; CTNO = conservation tillage only; STCC = standard tillage, cover crop; STNO = standard tillage only. Cover crop treatments include more tractor passes for mowing in conservation tillage, and mowing and incorporation in standard tillage.

TREATMENTS

CTCC: conservation tillage, cover crop

CTNO: conservation tillage only

STCC: standard tillage, cover crop

STNO: standard tillage only

TABLE 2. Soil bulk density in 2003, after 4 years of treatment*

Treatment	CTCC	CTNO	STCC	STNO
	g/cm³			
0–6 inches				
Average	1.20b†	1.05a	1.28c	1.24bc
Std. error	0.036	0.015	0.034	0.021
6–12 inches				
Average	1.42e	1.36e	1.37e	1.35d
Std. error	0.057	0.030	0.041	0.026

* CTCC = conservation tillage, cover crop; CTNO = conservation tillage only; STCC = standard tillage, cover crop; STNO = standard tillage only.

† Values not followed by the same letter are significantly different at the 5% confidence level.

the San Joaquin Valley. In 1999, we established a field experiment comparing standard and conservation tillage systems at the UC West Side Research and Extension Center (WSREC) in Five Points. The area generally receives only 7 inches of precipitation per year and has an average annual temperature of 63°F. These field plots are California's longest existing field research of conservation tillage systems.

Four treatments were applied: (1) conservation tillage with cover crop (CTCC); (2) conservation tillage, no cover crop (CTNO); (3) standard tillage with cover crop (STCC); and (4) standard tillage, no cover crop (STNO). Each treatment was replicated eight times and distributed randomly across the field. The treatments were split into four replicates each of tomato and cotton in alternating years. In this experiment, conservation tillage did not completely eliminate soil disturbance; rather, it reduced the number and intensity of tillage passes (table 1). The winter cover crop was a cereal-legume mix of Juan triticale (30%), Merced ryegrain (30%) and common vetch (40%).

Soils were sampled to two depths (0 to 6 inches and 6 to 12 inches) in the spring before planting and after the fall harvest. Total carbon and nitrogen were measured using a Carlo Erba carbon and nitrogen analyzer. The DANR Analytical Laboratory analyzed soil samples for the following soil properties: pH, electrical conductivity, nitrate-nitrogen, ammonium-nitrogen, and extractable potassium and phosphorus. The treatments and sampling protocols were repeated for four growing seasons. We applied a three-way ANOVA and Tukey's honestly significant difference (HSD) test to each dataset in order to determine significant differences between means (Tukey 1953).

Physical properties of soil

Texture. Soil texture was measured by the hydrometer method. In our study, soil texture varied across the field. The north half of the field was sandy clay loam with 51% sand, 24% silt and 25% clay, whereas the south half had a finer texture of clay loam with 36% sand, 33% silt and 31% clay. The treatments were blocked and randomly distributed across the field to account for the variance in texture.

Bulk density. Bulk density is a measure of soil's weight or mass per unit volume; soil with lower bulk density has more pore space and allows for more water infiltration and space for roots to grow than soil with higher bulk density. After 4 years of conservation tillage and cover cropping, we found bulk density differences in the surface 6 inches of soil (table 2). Soil bulk density was lowest with conservation tillage and highest with standard tillage. Bulk density was higher in the 6- to 12-inch depth than in the surface 0 to 6 inches for all treatments.

Changes in bulk density can usually be correlated to changes in the soil's organic matter. Organic matter organizes soil mineral particles into structural units that improve porosity, thereby decreasing bulk density. In our study, organic matter (total soil carbon) and bulk density were not correlated. Instead, bulk density more closely corresponded to the number of tractor passes required to manage each system. Each time the tractor passes across the field it compresses the soil and increases the bulk density. Generally, standard tillage and cover cropping treatments require more tractor passes; as expected, these treatments had higher bulk densities.

However, in our study CTCC required only one more tractor pass than CTNO, but its bulk density was 1.20 grams per square centimeter (g/cm^3) as compared to 1.05 g/cm^3, respectively. This significant difference is difficult to explain by the loss of one tractor pass. Unfortunately, bulk density was not measured when the study began, so we cannot make a time-zero comparison. Nonetheless, the treatments were randomly distributed across the field, and the differences between treatment means after 4 years of conservation tillage seem larger than would be found initially across a uniformly treated field. In this study, soil bulk density generally increased with increased compaction from tractor use, but we would expect these short-term observations to change as organic matter increases in the cover crop treatments.

Penetration resistance. Penetrometer resistance measurements of soil can be used to assess the need for tillage operations, which help maintain effective plant rooting and facilitate good water and nutrient uptake. Because deep tillage was eliminated in the conservation tillage plots, there was some concern that root penetration in the deep soil zones of those plots would be limited as a result of compaction caused by the equipment used for harvest, tillage and other cultural practices.

Our resistance measurements found little difference in soil compaction in the 0- to 9-inch depth, and the standard tillage plots had higher soil resistances at the 9- to 18-inch depth compared to the conservation tillage plots (fig. 1). These differences provided evidence that a compacted layer or plow pan was developing. This is caused by additional tillage activities during the spring, at a time when the moisture content in the subsoil is high and soils are more vulnerable to compaction.

Jeff Mitchell, UC Davis Cooperative Extension specialist, samples a triticale–winter rye–vetch cover crop on conservation tillage at the West Side Research and Extension Center in Five Points, Calif.

Carter et al. (1965) demonstrated the linkage between cotton yield and penetrometer resistance measurements in sandy loam soils and observed that resistances above 1,500 kilopascals (kPa) could result in lower lint yields. With penetration resistances up to 4,000 kPa in the 9- to 18-inch depth of the standard tillage systems, we expected these cotton lint yields to be lower than the conservation tillage treatments. However, in this study cotton yields were significantly higher with standard tillage than conservation tillage, so some other factors were limiting conservation tillage cotton production.

Chemical properties of soil

pH. Soil pH did not change significantly over the 4-year study. In 2000, pH across the field at both measured depths was 7.8 on average. In 2004, pH averaged 7.6 in the surface and 7.7 in the 6- to 12-inch depth, not a significant change in pH.

Electrical conductivity. As a soil's salinity level increases, the electrical conductivity (EC) of the soil solution also increases, so that EC is a measure of relative salt concentrations or salinity. Too much salt in soil can interfere with root function and nutrient uptake. EC increased significantly in CTNO at the surface from 0.88 deciSiemens per meter (dS/m) to 1.69 dS/m between 2000 and 2004. With CTNO, EC also increased to 1.30 dS/m in the 6- to 12-inch depth, but the change was not significant (table 3). EC remained the same in the rest of the treatments and depths.

The increase in EC at the surface in the CTNO treatment likely occurred because the fertilizer salts were not mixed into the soil; salts may also move to the surface during evaporation and then accumulate when not remixed by tillage. With standard tillage, salts are mixed and distributed throughout the plow layer. In winter, cover crops also may take up some of the fertilizer salts and prevent their accumulation at the surface.

The EC threshold for tomato production is 2.5 dS/m; above this the soil becomes too salty and tomato

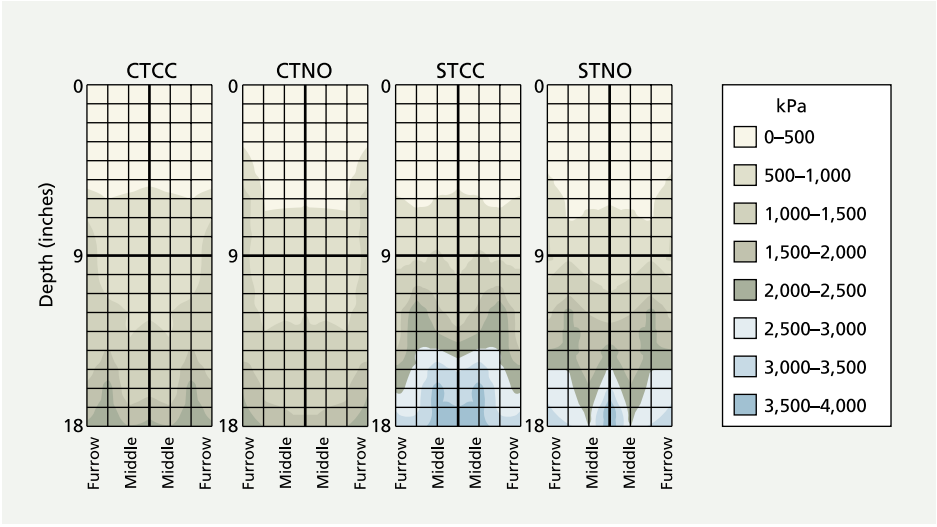

Fig. 1. Penetrometer readings from furrow to furrow by depth across treatments. Higher values (kPa) indicate greater penetration resistance.

yields can drop by 10% (Maas 1986). Measured salt concentrations were within this boundary during our 4-year study. (Cotton is more salt-tolerant than tomato.) If salts continue to concentrate at the surface in the CTNO treatment, the production of tomato and other salt-sensitive crops would be limited under conservation tillage, especially in parts of California where salt accumulation is a problem, such as the west side of the San Joaquin Valley. However, cover cropping may mitigate this potential salt accumulation.

Carbon. Total soil carbon is used to estimate soil organic matter, which is made up primarily of carbon. Soil organic matter is a reservoir of nutrients for plants and microorganisms; it helps to create soil structure, which gives the soil its porosity and allows more space for water and air, benefiting plant growth. Although we expected to see increases in total soil carbon with decreasing tillage, we actually found the largest loss in total carbon in the top 12 inches of soil in the CTNO treatment (table 3). This overall decrease may have been caused by the initial change in land use from barley to a cotton-tomato rotation; the cotton and tomato crops may have provided less carbon input than the previous barley crop. The STNO system lost only half as much carbon as CTNO.

The standard tillage system incorporates crop residue into the soil, where it is transformed into organic matter by microbial action. In conservation tillage, crop residue is not mixed into the soil mechanically. Instead, the system is dependent upon soil fauna such as beetles and worms to mix plant residue into the

TABLE 3. Soil chemical properties after 4 years of treatment*

	CTCC		CTNO		STCC		STNO	
	2000	2004	2000	2004	2000	2004	2000	2004
Electrical conductivity (dS/m)								
0–6 in.	0.84	1.23	0.88	1.69†	0.93	0.99	0.86	1.06
6–12 in.	0.98	0.87	0.85	1.30	0.82	1.07	0.88	1.16
Average 0–12 in.	0.91	1.05	0.865	1.495†	0.875	1.03	0.87	1.11
Difference‡	n.s.§		0.63		n.s.		n.s.	
Carbon (lb/acre)								
0–6 in.	10,081	15,243†	9,954	10,292	10,149	12,698†	9,906	10,001
6–12 in.	10,194	9,489	10,268	8,071†	9,988	11,455†	10,041	8,954†
Average 0–12 in.	10,137	12,366†	10,111	9,181†	10,068	12,076†	9,973	9,477†
Difference	+4,457		−1,859		+4,016		−992	
Nitrogen (lb/acre)								
0–6 in.	1,323	1,569†	1,302	1,117†	1,338	1,393	1,287	1,487†
6–12 in.	1,325	1,638†	1,461	1,356	1,304	1,494†	1,402	1,737†
Average 0–12 in.	1,324	1,603†	1,381	1,236†	1,321	1,443†	1,344	1,612†
Difference	+559		−290		+245		+535	
Nitrate (ppm)								
0–6 in.	18	18	17	33†	17	10	17	19
6–12 in.	19	14	18	25	15	10	16	19
Average 0–12 in.	18.5	16	17.5	25†	16	10	16.5	19
Difference	n.s.		+11.5		n.s.		n.s.	
Ammonium (ppm)								
0–6 in.	8.7	3.0†	8.8	1.5†	7.7	3.6†	7.5	1.2†
6–12 in.	9.2	1.7†	9.1	2.1†	8.2	2.1†	11.4	1.4†
Average 0–12 in.	9.0	2.4†	9.0	1.8†	8.0	2.9†	9.45	1.3†
Difference	−6.8		−7.2		−5.1		−8.2	
Olsen extractable phosphorus (ppm)								
0–6 in.	7.3	24†	8	19.3	7.7	8.3	7.8	9.5
6–12 in.	7.4	5.6	8.4	14.8	7.4	6.3	7.3	8.3
Average 0–12 in.	7.4	14.8†	8.2	17.1†	7.6	7.3	7.6	8.9
Difference	+7.5		+8.8		n.s.		n.s.	
Extractable potassium (ppm)								
0–6 in.	251	401†	278	383†	279	347†	270	322
6–12 in.	266	227	278	224†	263	292	272	279
Average 0–12 in.	258	314†	278	303	271	319†	271	300
Difference	+56		n.s.		+48		n.s.	

* CTCC = conservation tillage, cover crop; CTNO = conservation tillage only; STCC = standard tillage, cover crop; STNO = standard tillage only. Values are reported for the 0–6 inch depth and 6–12 inch depth, as well as overall averages for the entire 0–12 inch depth.

† 2004 values significantly different from 2000 values.

‡ Overall differences are listed if the 2004 average for the 0–12 inch depth was significantly different from 2000 average. Statistically significant differences were determined by Tukey's HSD test to a 5% confidence level.

§ Nonsignificant difference.

soil. Soil fauna populations may take more than 4 years to regenerate after decades of intensive tillage. In the conservation tillage systems, crop residue may be accumulating and mineralizing on the soil surface and not incorporating into soil to produce organic matter.

Researchers have found increases in total carbon with decreasing tillage, but most of this research was conducted in the temperate, humid, eastern half of the United States. Researchers in Texas found that soil carbon accumulation is inversely related to mean annual temperature, and that hot, dry conditions create a challenging environment for increasing soil carbon (Potter et al. 1998). The hot, dry conditions of the San Joaquin Valley's west side may limit the ability of conservation tillage to accumulate soil carbon in this region.

In our study, the addition of cover-crop residues increased soil carbon regardless of tillage practice. CTCC and STCC increased total carbon by an average of 4,200 pounds per acre after 4 years. Cover crops, by adding more biomass to the system, increase carbon inputs to the soil. In CTCC, more carbon was found in the upper 6 inches, and

After 4 years of conservation tillage, the soil's physical properties improved but its fertility degraded somewhat.

there was no change in total carbon in the 6- to 12-inch depth. Carbon accumulates in the upper 6 inches in conservation tillage because the crop residues are left on the surface and not tilled into the soil. Conversely, with STCC total carbon increased in both depths because the residues were incorporated and mixed into the soil. After 4 years, changes in total carbon were influenced more by cover-crop additions than tillage.

Other studies have shown that carbon increases in no-till systems in similar hot, semiarid climates after 10 years (Zibilske et al. 2002; Mrabet et al. 2001). Others found increases in total carbon at the surface after 10 years, but no overall carbon accumulation because of losses from lower depths (Hernanz et al. 2002). Also, conservation tillage in our study did not mean the complete elimination of soil disturbance; rather, the system included some cultivation in tomato and postharvest tillage in cotton. Even this reduced soil disturbance may have limited carbon accumulation in the conservation tillage systems.

TABLE 4. Total nitrogen (N) and carbon (C) budget after 4 years of treatment*

Nitrogen

Crop	Treatment†	Fertilizer	Cover crop	Total	Harvest	Balance
				lb N/acre/yr		
Cotton	CTCC	45	149	194	20	174
Cotton	CTNO	45		45	23	22
Cotton	STCC	45	118	163	24	139
Cotton	STNO	45		45	27	18
Tomato	CTCC	69	133	202	146	55
Tomato	CTNO	69		69	161	–93
Tomato	STCC	69	103	171	146	26
Tomato	STNO	69		69	144	–76

Carbon

Crop	Treatment†	Crop carbon	Cover crop	Total	Harvest	Balance
				lb C/acre/yr		
Cotton	CTCC	1,580	3,315	4,895	328	4,567
Cotton	CTNO	1,779		1,779	369	1,410
Cotton	STCC	1,899	2,618	4,516	394	4,122
Cotton	STNO	2,088		2,088	433	1,655
Tomato	CTCC	1,169	2,955	4,124	2,484	1,640
Tomato	CTNO	1,288		1,288	2,736	–1,448
Tomato	STCC	1,163	2,288	3,451	2,472	979
Tomato	STNO	1,152		1,152	2,448	–1,296

* For nitrogen, fertilizer nitrogen and cover-crop nitrogen are considered inputs, while harvested nitrogen is considered an output. For carbon, crop carbon and cover-crop carbon are considered inputs, while harvested carbon is considered an output. The balance is the nitrogen or carbon that should be remaining in the soil.

† CTCC = conservation tillage, cover crop; CTNO = conservation tillage only; STCC = standard tillage, cover crop; STNO = standard tillage only.

Nitrogen. Soil nitrogen is an important nutrient for plants and microbes; large amounts of nitrogen are needed to form amino acids, proteins and enzymes. In our study, CTNO lost 290 pounds nitrogen per acre after 4 years, while the rest of the treatments showed an overall accumulation of total nitrogen in the upper 12 inches of soil (table 3). CTCC increased by 559 pounds nitrogen per acre, and in STCC, total nitrogen increased by 245 pounds per acre. The increases in total nitrogen in these two systems are linked to the increased input of organic matter associated with the cover crop. However, the increase in total nitrogen in the STNO treatment was unexpected.

Carbon and nitrogen dynamics

In order to help us understand the carbon and nitrogen dynamics of this system, we calculated a carbon and nitrogen budget, in which we looked at all of the carbon and nitrogen inputs and removals from each system (table 4). For carbon, the remaining crop-residue carbon and cover-crop carbon were the inputs to the system, and the carbon removed with the harvested crop was the output. For nitrogen, fertilizer nitrogen and nitrogen fixed by cover crops were the inputs, and nitrogen removed by the harvested crop was the output. The balances of these inputs and outputs should predict the amount of carbon and nitrogen stored or lost by each of the treatments.

We compared the resulting balances to the overall increases and decreases in total soil carbon and nitrogen (table 5). Although the actual values were different, by and large the changes in total soil carbon corresponded to what was estimated by the budget. All of the actual total soil carbon values were about 1,100 to 1,800 pounds less than the expected values. This difference may be attributed to the fact that we only measured carbon in the surface 0 to 12 inches of soil. More soil carbon may be accumulating below 12 inches, especially from plant root inputs.

The differences between the budgeted and actual values of total soil

Cover crops in conjunction with conservation tillage helped to maintain soil fertility. *Left,* cotton and tomato crop residues prior to no-till transplanting; *center and right,* no-till cotton planting with a John Deere 1730 no-till transplanter directly into a cover crop of triticale–winter rye–vetch.

nitrogen were more variable. The CTCC and STNO treatments had much higher total soil nitrogen values than expected; STCC had a slightly larger value, while CTNO had a much larger loss than expected. Nitrogen is generally much harder to budget than carbon. The differences between the budgeted and actual values for the two cover-crop treatments suggest that the actual nitrogen fixation rate of the cover crop was larger than we estimated. The largest difference between expected and actual total soil nitrogen was in the STNO treatment, where we expected a total nitrogen loss and instead we saw an increase of 535 pounds nitrogen per acre. This difference is difficult to explain. The nitrogen budget does not account for nitrogen losses due to leaching or denitrification; these two processes may account for the higher than expected loss of total soil nitrogen in the CTNO treatment.

If total carbon and nitrogen values were used as an estimate for organic matter, we saw higher organic-matter mineralization potential in conservation tillage. This may be because the surface mulch allowed the soil to stay moist longer. In addition, as temperatures rose in the spring, more decomposition and mineralization occurred in the conservation tillage systems, so we saw overall losses of total carbon and nitrogen. But in the conservation tillage systems with cover crops, the extra biomass offset losses associated with the higher mineralization rate.

TABLE 5. Total nitrogen (N) and carbon (C) balance from the N and C budget (table 4) compared to total change in soil N and C

Nitrogen

Treatment*	Total balance	Total change in soil
	····· *lb N/acre/yr* ·····	
CTCC	229	559
CTNO	–71	–290
STCC	165	245
STNO	–58	535

Carbon

Treatment	Total balance	Total change in soil
	····· *lb C/acre/yr* ·····	
CTCC	6,207	4,457
CTNO	–38	–1,859
STCC	5,101	4,016
STNO	359	–992

* CTCC = conservation tillage, cover crop; CTNO = conservation tillage only; STCC = standard tillage, cover crop; STNO = standard tillage only.

Other minerals

Nitrate. The nitrification of ammonia-based fertilizer results in nitrate, the form of nitrogen that is most easily taken up by plants. Although we expected to see improved nitrate conservation with cover cropping, in all treatments except CTNO, nitrate concentrations remained the same in both depths after 4 years of treatment. In CTNO nitrate concentrations increased in the surface 6 inches from 17 parts per million (ppm) to 33 ppm (table 3).

Nitrate is a mobile ion that moves easily up and down the soil profile. With evaporation and upward water flow, nitrates can move to the surface, and without the physical mixing of tillage, the nitrate can stay in place and may contribute to salinity. In standard tillage systems where the profile is mixed regularly, nitrate is more evenly distributed throughout the profile. In the systems with cover crops, they take up nitrate, converting it to organic forms of nitrogen and preventing nitrate accumulation at the surface. In our study, conservation tillage systems accumulated nitrate in the surface (0 to 6 inches), while in standard tillage systems nitrate was evenly distributed throughout the upper 12 inches of soil.

Ammonium. Nitrogen fertilizer is often added to crops in the form of ammonia. All treatments and depths showed a decrease in ammonium concentrations after 4 years (table 3). These differences may be due to differences in the nitrification rate between the years, which could be affected by variations in winter temperatures and rainfall.

Phosphorus. Phosphorus is an essential component of DNA and RNA, making it another important plant nutrient. We found an overall increase in extractable phosphorus in both conservation tillage treatments, and phosphorus concentrations remained the same in both standard tillage treatments (table 3). In CTNO we saw an increase in each depth, but neither depth was considered significantly different than the 2000 value. With CTCC, the increase was in the 0- to 6-inch depth.

Conservation tillage usually improves the availability of surface phosphorus by converting it into organic phosphorus. Crops take up phosphorus from below, "mining" and depositing it on the surface. In standard tillage systems this phosphorus would be remixed into the soil profile, whereas in conservation tillage it accumulates at the surface (Robbins and Voss 1991; Zibilske 2002). The CTNO treatment appeared to behave this way, but in CTCC we saw phosphorus increase in both depths. However, despite an overall increase in organic matter, the STCC treatment did not show phosphorus accumulation.

Conservation of phosphorus may be a potential benefit of conservation tillage, improving phosphorus availability.

Potassium. After nitrogen and phosphorus, potassium is the nutrient most likely to limit plant production. In all treatments except STNO, potassium accumulated at the surface. Also, at the 6- to 12-inch depth, the potassium concentration remained the same, except in CTNO it decreased (table 3). In CTNO, crops took up potassium from the subsurface and deposited it as crop residue on the surface as organic matter. In the conservation tillage system the potassium stayed at the surface because it was not remixed by tillage. After 10 years of conservation tillage, Robbins and Voss (1991) found a similar redistribution of potassium to the soil surface. If this redistribution continues in our fields, it may eventually limit potassium availability to deeper-rooting crops or contribute to salinity problems. In the two cover-crop treatments, there was an overall potassium accumulation of about 100 ppm. By taking up and redistributing potassium to the soil surface, cover cropping and conservation tillage may be beneficial methods for conserving this important nutrient.

Overall effects on soil quality

In other parts of the United States, conservation tillage and cover cropping have been shown to improve soil quality. In our study, after 4 years of conservation tillage the soil's physical properties improved, but its fertility degraded somewhat. Bulk density and penetration resistance were lower in the conservation tillage systems; these soil properties improve water infiltration and conservation, and improve rooting depth. Conservation tillage increased available phosphorus but redistributed potassium from the subsurface to the surface by accumulating organic matter at the soil surface and not remixing it with tillage. Nitrate accumulated at the surface as well. By concentrating these nutrients at the surface, conservation tillage could limit crop growth and contribute to potential salinity problems.

This was seen in conservation tillage's affect on salt accumulation in the soil surface, which could create salt toxicity problems for crops with low salt-tolerance over the long term. With regard to organic matter or soil carbon — an important and beneficial property for long-term soil fertility and quality — we did not see any increases in the conservation tillage systems, but cover crops increased soil carbon significantly regardless of the tillage treatment. Cover cropping also increased total soil nitrogen, phosphorus and potassium, and in the conservation tillage treatments mitigated the increases in salt concentration. In the low-rainfall regime of the San Joaquin Valley, farmers may benefit more from cover cropping in combination with conservation or standard tillage to maintain soil fertility, as opposed to conservation tillage alone.

In this study, some soil parameters improved with conservation tillage, while others declined. For example, after 4 years of conservation tillage without a cover crop, soil salinity increased significantly. *Above,* researchers evaluate no-till planting into tomato residues.

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Dietary quality is not linked across three generations of black women

by Joanne P. Ikeda, Constance L. Lexion, Barbara J. Turner, Margaret C. Johns, Yvonne Nicholson, Mary L. Blackburn *and* Rita A. Mitchell

Many nutritionists believe that food habits are passed on from one generation to the next, influencing dietary quality. However, we studied the food habits and dietary quality among three generations of biologically related black women and found that there was no correlation or relationship. In addition, we identified culturally acceptable food sources of nutrients most likely to be lacking in the diets of black women. The increased consumption of these foods may help reduce the high rates of chronic diseases among black women in California.

Earhart Photography

To gauge how food habits are passed down through generations, the authors studied the diet and nutritional status of 58 triads (daughter, mother and grandmother) of biologically related California black women. *Left to right,* study participants Rhonda Carter (mother) and Mildred Ross (grandmother) of Victorville, and Catrice Mitchell (daughter) of San Bernardino.

For many health conditions, African-Americans bear a disproportionate burden of disease, injury, death and disability, and thus suffer from health disparities. In 2001, for example, about 40% of black males and females had cardiovascular disease, versus 30% for white males and 24% for white females in the United States (AHA 2006). In the same year, the age-adjusted incidence rates per 100,000 of cancer were substantially higher for black females than white females for colon/rectal (54.0 versus 43.3), pancreatic (13.0 versus 8.9) and stomach (9.0 versus 4.5) cancers (ACS 2000). The prevalence of diabetes is 70% higher among blacks as compared to whites in the United States, and among those with diabetes, blacks are 1.5 to 2.5 times more likely to suffer from lower limb amputations and 2.6 to 5.6 times more likely to suffer from kidney disease (ADA 2006).

These health risks are partly due to poor dietary habits, including diets high in fat, calories (Tibbs et al. 2001), sodium and cholesterol (Hargreaves et al. 2002), and low in fruits and vegetables (Tibbs et al. 2001) and dietary fiber (Hargreaves et al. 2002). Improving the diets of African-Americans is one of the simplest and most effective ways to reduce their risk of chronic disease and improve their overall health.

The successful promotion of nutrition awareness among African-Americans should include health education programs that are tailored to their community, because the need for cultural appropriateness in such programs is well documented (Marin et al. 1995). In addition, research to identify influences on disease and disease management is essential for successful national prevention efforts (Clark and McLeroy 1995). Research on psychosocial characteristics is critical and should focus on attitudes, norms, values and expectancies related to health-damaging or health-protecting behaviors. Such research, investigating health-damaging behaviors and the avoidance of prevention-oriented actions, is urgently needed if these behaviors are to be reduced (Marin et al. 1995). Certainly, improvement in nutrition status and disease prevention in blacks should include research into cultural and psychosocial factors that affect food habits and dietary quality.

Generational dietary studies

One possible influence on dietary quality is the passing down of food habits in families from one generation to the next, a notion often promulgated by nutritionists. If that were the case, one would expect to see some relationship between the dietary intakes of succeeding generations. Surprisingly, there are few published studies examining resemblances in food habits, dietary quality and nutrient intakes across generations of biologically related adults.

A study of three generations of Dutch women living separately found weak correlations of nutrient intake (energy, fat and cholesterol) between generations (Stafleu et al. 1994). Similarly, a study of parents and children in France found weak correlations for energy and macronutrient intakes between generations (Vauthier et al. 1996). In contrast, a study of three generations of Canadians (children, mothers and maternal grandmothers) found differences in dietary patterns between generations, and the researchers suggested that generations may respond differently to nutrition recommendations and dietary guidelines (Lemke et al. 1998). For example,

the mothers' number of servings of fats and oils was significantly higher than that of the children and grandmothers, while children had the highest number of servings of sweets and desserts.

Researchers often report differences in food habits or nutrient intakes between ethnic or cultural groups (Clark and McLeroy 1995; Lovejoy et al. 2001; Huang et al. 2002; Forshee et al. 2003). We wanted to look at differences within one ethnic group. Significant differences have been found within an ethnic group (Native Americans) by dividing the women into two groups: more adequately nourished and less adequately nourished (Ikeda et al. 1998). The researchers identified eating habits that were associated with the more adequately nourished women, and then used them as the basis for nutrition education within the Native American community. In other words, the positive habits of the more adequately nourished women were held up as models for less adequately nourished women within the same ethnic group.

UC Cooperative Extension nutritionists conducted a survey of food habits and dietary quality among three generations of biologically related black women: daughters, mothers and grandmothers. The purpose of the survey was to identify generational relationships and information about attitudes, beliefs and dietary practices that could be used to design culturally appropriate approaches to nutrition education for black women. The study was intended to help determine whether different approaches and messages need to be tailored for each generation. The researchers also wanted to identify health perceptions and practices related to food acquisition and preparation that could be used to design culturally appropriate nutrition education materials for black women.

Nutrition survey

An advisory committee of Nutrition Advisors (Cooperative Extension Nutrition, Family and Consumer Science Advisors), most of whom were black, guided the study. Based on their extensive professional experience, these advisors determined the kinds of information most useful in designing culturally appropriate nutrition education programs for black women. (Permission to conduct this study was obtained from the Committee for the Protection of Human Subjects at UC Berkeley.) The committee chose to focus on food acquisition practices, food preparation skills, meal and snack patterns, and health practices and beliefs. A questionnaire was developed and reviewed by the advisory committee for cultural relevance and appropriateness. The revised questionnaire was pilot-tested on five women from the target population.

The Nutrition Advisors could not identify a food frequency questionnaire designed specifically for blacks, so a 24-hour food recall was used to collect dietary intake data. The 24-hour food recalls were used to determine nutrient intake and the number of servings from the major food groups.

Study participants were recruited through the Expanded Food and Nutrition Education Program (EFNEP), churches and other organizations serving black communities. Participants were interviewed in their homes, unless they preferred another location.

The Nutrition Advisors measured the heights and weights of participants, using electronically calibrated scales and stadiometers (used to measure height). This information was used to investigate the relationship between body mass index (BMI) and self-reported food habits and dietary quality. Demographic information collected included age, county of residence, birthplace, length of time in California, education, family size, income and participation in federal food-assistance programs. Nutrition Advisors responsible for data collection attended an all-day training meeting on instruments and the standardized methods of implementation.

All data was sent to the Department of Nutritional Sciences and Toxicology at UC Berkeley for coding, computer entry and data analysis. The food recalls were coded by a dietitian, who also determined the number of servings from each of the major food groups. To assess dietary quality, the 24-hour food recalls were analyzed using the U.S. Department of

ABBREVIATIONS

AI: Adequate Intakes

DRI: Dietary Reference Intake

LAN: Less adequately nourished

MAN: More adequately nourished

RDA: Recommended Dietary Allowance

Earhart Photography

While the dietary quality of grandmothers appeared to be related to that of the mothers, by the next generation of daughters this positive influence had waned. *Left to right,* study participants Michelle Beauregard (mother), Valerie Pope-Ludlam (grandmother) and Valerie Beauregard (daughter), all of San Bernardino.

Parents and children are eating more meals apart and making more independent food choices.

Agriculture (USDA) Nutrient Database for Individual Intake Surveys (v. 4, 1991, Human Nutrition Information Service, Hyattsville, Md.). Mean and median values were calculated for 15 nutrients, as were the percentages of the 1997 to 2003 Dietary Reference Intakes (DRIs), specifically using Recommended Dietary Allowance (RDA) and Adequate Intake (AI) values (U.S. Institute of Medicine 1997, 1998, 2000a, 2000b, 2005). DRIs are a set of at least four nutrient-based reference values that can be used for planning and assessing diets and for many other purposes. They are meant to replace the former RDAs. Due to the large standard deviations in nutrient intakes, the women were categorized on the basis of the number of nutrients at or above two-thirds of the DRI. This yielded a more accurate description of dietary quality, and a score was given to each participant based on the number of nutrients at or above two-thirds of the DRI.

Women were categorized as "more adequately nourished" (MAN) if their diets contained two-thirds or more of the DRI for at least 12 of the 15 nutrients, or as "less adequately nourished" (LAN) if their diets did not meet two-thirds of the DRI for at least three of the 15 nutrients. Even though using two-thirds of the RDA/AI as a criterion to define nutrient adequacy is not a common procedure, this value was selected as a convenient cut-off point to distinguish nutrients that were very low in a diet, such that the LAN scores could be derived to describe diets that were inadequate in multiple nutrients. The data was collected in 1995 and reanalyzed for the RDI amounts issued in 1999. This data reflects the dietary relationship of three generations at a point in time when health disparities were becoming an important issue in minority communities.

The food habit questionnaires were also analyzed to determine which habits were related to dietary quality (including dieting history, attitudes toward and perceptions of healthy food practices, and food security issues), and which habits were related to the frequency of specific eating patterns (such as snacking, eating at fast food restaurants and watching television during meals).

Statistical analysis. Chi-squared methods were employed to evaluate the relationship of dietary quality with categorical variables, while two sample *t*-tests were used for continuous variables. Multiple regressions techniques were used, adjusting for energy/calorie intake. Because subjects from the same family are not statistically independent, a generalized estimating equation program was used to adjust for correlations within families (Karim and Zegen 1988).

TABLE 1. Participant profiles of daughters, mothers and grandmothers

	Daughters (n = 58)	Mothers (n = 58)	Grandmothers (n = 58)
Age	16 to 32, mean = 21	33 to 52, mean = 42	49 to 76, mean = 65
Family size	2 to 8, mean = 4	1 to 8, mean = 4	1 to 7, mean = 3
Monthly per capita income	$272	$452	$606
Education:			
8th grade or less	8	7	18
High school	27	13	21
2-year vocational school	17	29	14
College, graduate school	6	9	4
No. born in Calif.	56	32	4
How long in Calif.	5 to 32 years, mean = 21 years	20 to 52 years, mean = 37 years	10 to 70 years, mean = 43 years
No. currently employed	27	41	17
Household participation in federal assistance programs:			
WIC	20	9	5
Food stamps	21	14	9
AFDC	25	15	11

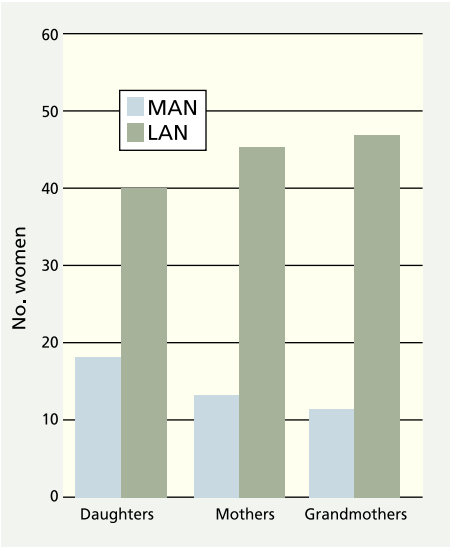

Fig. 1. Dietary quality by generation (n = 58 triads). MAN = more adequately nourished; LAN = less adequately nourished.

Repeated measures analyses of variance (RANOVA) were conducted to compare the three generations for food group intakes. For all statistical tests performed, $P < 0.05$ was considered to be statistically significant.

Diet quality not linked in families

We were able to profile 58 triads of biologically related daughters, mothers and grandmothers (174 women total) (table 1). The number of participants born in California increased with each generation. Almost all of the daughters were born in California, whereas most of the grandmothers were born in the South. Each generation of daughters was increasingly dependent on WIC and food stamps; the impact of this trend on dietary quality was investigated and found to be null. When choosing our subjects, we made sure that there was little overlap between the ages of the three generations, so that each generation would have experienced social, cultural and political influences distinct from those of the other two generations. Distinct separation of the ages of each generation is important in cross-generational studies, because the time period experienced by each generation needs to be different (Jackson and Hatchett 1986).

Related factors. In determining which factors were correlated with dietary quality, each generation was analyzed separately, and the entire

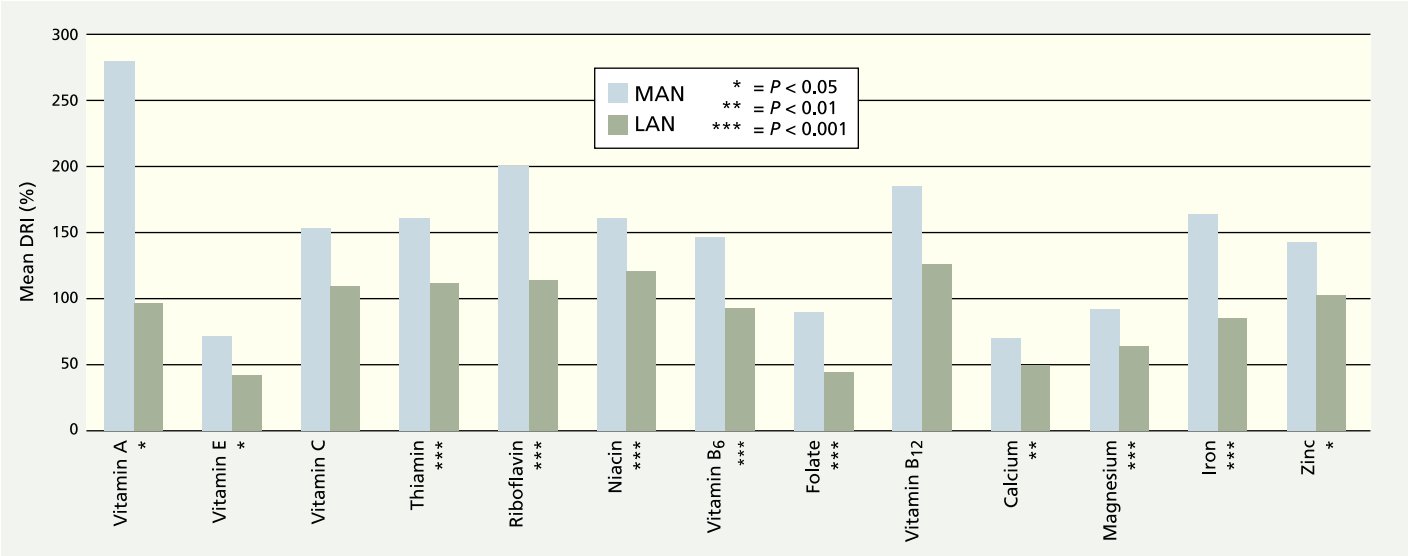

Fig. 2. Percentage of Dietary Reference Intake (DRI) for selected nutrients, adjusted for caloric intake (n = 174). Mean percentage DRI of each nutrient was determined by dividing average intake by DRI value. Statistical difference between MAN (more adequately nourished) and LAN (less adequately nourished) determined by analysis of covariance, adjusted for caloric intake.

sample was analyzed together. Unless noted, the factors associated with dietary quality were significant when looking at all three generations at one time without separating them from one another.

Out of the entire sample of women from all three generations, 132 women (76%) were LAN and 42 women (24%) were MAN (fig. 1). When each generation of women was analyzed separately, there was a consistent trend of more LAN than MAN women. When the three generations were compared to each other, the difference in the number of women in each generation who were MAN and LAN was not significant. One generation was no better nourished than another.

Mean caloric intake was positively related to dietary quality. The mean caloric intake of MAN women was 2,841 calories, and the mean caloric intake of LAN women was 1,574 calories ($P < 0.001$). Interestingly, weight status was not an indicator of dietary quality, as many normal weight and severely overweight women were less adequately nourished. Nutrient intakes were analyzed while adjusting for energy intakes in order to identify differences in nutrient density of the diet. With the exception of vitamins C and B_{12}, the data showed significant differences in the nutrient intake between the MAN and LAN groups. The diets of MAN women had significantly greater nutrient density for protein (not shown), phosphorus (not shown), calcium, magnesium, iron, zinc, thiamin, riboflavin, niacin, folate, and vitamins A, E and B_6 (fig. 2).

The numbers of servings of the major food groups in the Food Guide Pyramid (USDA 1992) for the three generations showed statistically significant differences between the MAN and LAN groups in the number of servings of vegetables and dairy ($P < 0.05$), but not of fruits, grains or meat (fig. 3). The number of meals eaten each day was related to dietary quality ($P < 0.01$), with three or more per day reported by 57% of MAN women but only 31% of LAN women. Many other factors were not related to dietary quality in this study, either for all generations together or for each generation separately.

Generational comparison. The dietary quality scores of participants within each triad, defined as the total number of nutrients at or above two-thirds of DRI, were compared to determine if one generation influenced the quality of the dietary intake of another generation. The dietary quality scores of the grandmothers were positively related to those of the mothers ($P < 0.05$). However, this positive influence tended to disappear by the next generation. In fact, the dietary quality scores of the grandmothers were negatively related to those of the daughters ($P < 0.01$). The significance of a negative

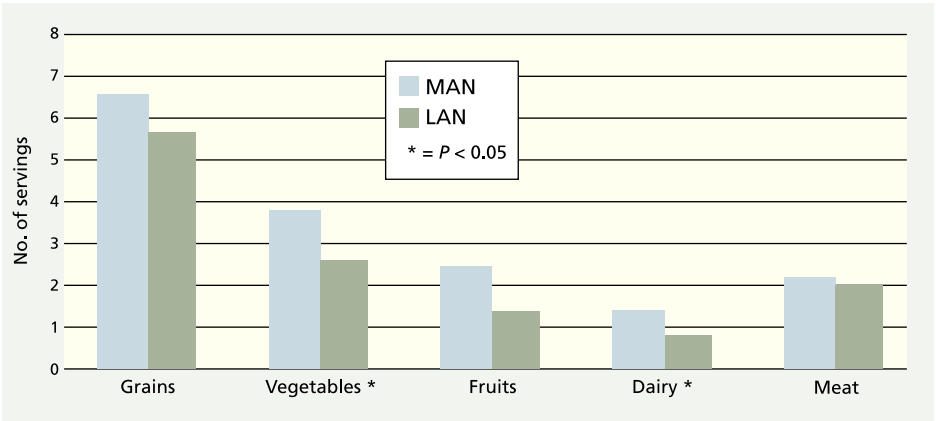

Fig. 3. Influence of number of daily servings from Food Guide Pyramid food groups on dietary quality, adjusted for energy intake (n = 174). Statistical difference determined by analysis of covariance, adjusted for caloric intake. MAN = more adequately nourished; LAN = less adequately nourished.

correlation was unclear, but this result confirmed that the dietary quality of the grandmothers did not positively influence that of the daughters. Additionally, there was no relationship between the dietary quality scores of the mothers and the daughters, even though they may have lived together. This was a surprising finding because it was previously assumed that female family members in the same household would have similar food intakes and similar dietary scores.

Milk and meat consumption. When all three generations were considered together, women who reported drinking milk on a regular basis had 24-hour recalls with significantly higher calcium intakes (672 milligrams per day) than those who did not (498 milligrams per day) ($P < 0.01$). When individual generations were analyzed for differences in calcium intake between women who regularly drank milk and those who did not, the only significant difference was found among the mothers. Mothers who reported drinking milk on a regular basis had an average daily calcium intake of 641 milligrams, compared to 462 milligrams for mothers who did not drink milk regularly ($P < 0.05$).

We compared the number of servings of each of the major food groups of the Food Guide Pyramid by generation. Daughters consumed significantly fewer servings from the meat group (1.5 servings) than mothers (2.2 servings) or grandmothers (2.5 servings) ($P < 0.001$). Generational differences in consumption of other food groups were not significant.

At-risk nutrients. Vitamin E was an at-risk nutrient for the greatest number of women when all three generations were considered together (table 2). Overall, the greatest numbers of all participants had less than two-thirds of the DRI for vitamin E (144 of 174; 83%), calcium (122 of 174; 70%), folate (120 of 174; 69%) and magnesium (91 of 174; 52%).

TABLE 2. Ten at-risk nutrients most lacking in the diets of each generation; number of women who consumed less than two-thirds of the DRI for these nutrients

Daughters (n = 58)		Mothers (n = 58)		Grandmothers (n = 58)	
Vitamin E	45	Vitamin E	45	Vitamin E	54
Folate	40	Calcium	45	Calcium	48
Calcium	29	Folate	40	Folate	40
Magnesium	29	Iron	31	Magnesium	32
Vitamin A	26	Magnesium	30	Vitamin B_6	26
Vitamin C	25	Vitamin C	23	Vitamin A	24
Iron	24	Vitamin A	21	Zinc	21
Vitamin B_6	17	Vitamin B_6	14	Vitamin B_{12}	21
Zinc	14	Zinc	13	Vitamin C	19
Niacin	11	Riboflavin	10	Thiamin	14

Comparison with other studies

Before the second half of the 20th century, food habits may have been passed down from one generation to the next, influencing dietary quality. This may still be the case in rural areas of less rapidly developing countries, where people's lifestyles and environment are not much different today compared to 50 years ago. However, dramatic changes in lifestyle and environment in the United States appear to have had a tremendous impact on eating patterns and food choices (Crockett and Sims 1995). Any influence that one generation might have on the food habits and food choices of subsequent generations appears to be nullified by an ever-changing food supply and an increasingly complex lifestyle.

Therefore, it is not surprising that we did not find a positive relationship between the dietary scores of biologically related grandmothers and granddaughters. The weak relationship between the dietary scores of grandmothers and mothers may be indicative of the stronger influence of family relationships in the past. The null relationship between the diets of mothers and daughters is indicative of the reality of parents and children eating more meals apart and making more independent food choices. These findings are consistent with those mentioned earlier from other studies of dietary habits across generations (Stafleu et al. 1994; Vauthier et al. 1996; Lemke et al. 1998).

Several studies in the United States have followed cohorts of black women, as well as women of other ethnic groups. Researchers reported dietary variations among ethnic groups (Lovejoy et al. 2001; Huang et al. 2002; Forshee et al. 2003). However, most researchers did not distinguish between the more adequately nourished and less adequately nourished women within ethnic groups.

Because other studies have reported mean intakes on an entire group of black women, it is difficult to make many comparisons with our results. However, there are several nutrients in which comparisons are possible. Our finding that the protein intake of black women exceeded the DRI is consistent with the results of other studies (Lovejoy et al. 2001; Huang et al. 2002; Forshee et al. 2003). Our data showing adequate intakes of zinc, thiamin and vitamins A, C and B_6 in the more adequately nourished women were consistent with the previous results. Similarly, the low intakes of vitamin E, folate and calcium found in this survey were consistent with those reported in these other surveys.

It is generally recognized that estimating intake of fat-soluble vitamin E is difficult, because both caloric and fat intakes are probably underreported, and the amounts and types of fats and oils used in food preparation are difficult to assess. Mean intakes of apparently healthy adults in the United States are likely to be above the RDA of 15 milligrams of α-tocopherol (the only form of vitamin E maintained in human blood plasma). Current dietary patterns appear to provide sufficient vitamin E to prevent deficiency symptoms (Monsen 2000).

There are some possible limitations to our study, as the data is based on self-reported 24-hour dietary recalls and questionnaires. Inaccurate estimation of dietary quality may result from atypical diets on the day of the recall or errors in self-reporting. Self-reported dietary recall data may be skewed from underreporting, which would lead to the underestimation of calories and nutrients. Self-reported estimates of other factors, including food habits and socioeconomic factors, may also be biased.

Improving food habits

In our study, no individual generation of black women was better nourished than another generation. The dietary quality of all three generations of black women could be improved substantially by mimicking the food choices of more adequately nourished black women. In this study, women from all three generations who were more adequately nourished ate three or more times a day, selected a variety of foods from the Food Guide Pyramid and did not restrict caloric intake to the point that it had a negative impact on nutrient intake. Women who reported drinking milk on a regular basis had higher intakes of calcium than those who did not.

Nutrition professionals should encourage black women to adopt the eating habits of these better-nourished women. When working with black women, nutrition professionals should also pay particular attention to encouraging foods that contain nutrients likely to be lacking in the diets of all three generations, including calcium, folate and magnesium. On the 24-hour food recalls, participants reported a number of foods that are rich in these nutrients, including nuts and seeds, dry beans, greens, broccoli, melon, fish, reduced-fat milk, cheese, oatmeal and cornbread. Since the better-nourished women in the study consumed these foods, they are likely to be acceptable to other black women.

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Steve Prezant/Corbis

In this study, the more adequately nourished women ate three or more meals a day, consumed a wide variety of foods and drank milk regularly.

Western cattle prices vary across video markets and value-adding programs

by Steven C. Blank, Hayley Boriss, Larry Forero *and* Glenn Nader

We analyzed video auction sales in the western United States from 1997 to 2003, in an attempt to answer two long-standing questions about the economics of cattle ranching in California. First, as expected, ranchers received lower prices for cattle sold here compared to prices received by ranchers in the Midwest; this is due to the cost of transporting cattle to Midwestern feedlots. Second, some (but not all) "value-adding" production and marketing practices — such as preconditioning, Quality Assurance Programs and natural beef production — did raise prices received by ranchers. We report on the average location discounts and quality premiums for several market regions.

Alison Van Eenennaam

Western cattle ranchers have long suspected that they receive lower prices than ranchers located closer to Midwestern feedlots. The study showed that higher transportation costs accounted for much of this discrepancy. *Above,* a herd at the UC Sierra Foothill Research and Extension Center.

California's cattle ranchers have long suspected that buyers offer lower prices here than they do for similar cattle in the Midwest. The primary reason for this price discounting is generally believed to be because most U.S. feedlot, slaughter and packaging facilities are located in the Midwest, and ranchers in California and other Western states must pay to ship calves to these facilities. Indeed, the cost of that transportation is the basis for price discounts offered in Western markets compared to those offered in markets located closer to the Midwestern meat-processing industry (Clary et al. 1986). However, in the past it was difficult to calculate exactly how much of the price differences observed in Western versus Midwestern cattle sales was due to transportation costs as opposed to other factors, such as differences in the physical attributes of the animals.

Cattle markets signal what they value by offering a price premium for animals that possess desired characteristics (Mintert et al. 1990). Consequently, ranchers have developed production and marketing programs aimed at producing cattle with characteristics thought to add value.

In recent years there has been much discussion in the cattle industry about whether preconditioning weaned calves before sending them to market adds to their sales value. Preconditioning is a special type of management program aimed at making calves more valuable to buyers. Several preconditioning programs have been discussed, including various respiratory-vaccination and weaning programs. For example, two research projects conducted by Colorado State University in 1997 and 1999, with video auction data from 1996 to 1997 and 1995 to 1998, respectively, both reported that combined vaccination and weaning programs resulted in higher average prices than those received by sellers of unvaccinated calves (King 2003). In those studies, price premiums were reported as high as $3.89 per hundredweight (cwt).

Likewise, a study conducted by Oklahoma State University in December 2000 found that price premiums were received for preconditioned calves, but the premium was not enough to cover preconditioning costs (Avent et al. 2004). These studies focused on preconditioning, assessing its market effects. However, many factors influence cattle prices and those influences are often interactive.

Our research focused on price differences in calf markets across locations and across value-adding programs. We were able to estimate both the average transport-based price discounts and individual value-added program premiums received by ranchers. This new analysis gives a current picture of the market value of transportation and other pricing factors, such as preconditioning.

Cattle market economics

The basic price of an agricultural commodity is determined by the supply of, and demand for, the product in a

local market. However, that basic price must be adjusted across locations to get a more complete picture of the prices received by cattle producers. Previous economic research has found that prices observed at different locations at one point in time will differ by amounts up to the cost of transporting the product from one place to another. If price differences between locations exceed transportation costs per pound, it is possible for someone to buy cattle in the low-price market and immediately sell them in the high-price market after transporting the animals, and profit from doing so. This "arbitrage" process reduces cattle supplies in the low-price market and increases supplies in the high-price market, pushing prices in the two locations closer together until all potential for arbitrage profit is eliminated. In the highly efficient U.S. cattle market, few arbitrage opportunities appear because market participants react quickly to those opportunities, and their actions restore price differences to levels equal to or less than transportation costs.

A second issue regarding cattle prices over different locations involves the structure of the U.S. beef industry and its location. This structure is determined by the components of the final product consumed and the costs of bringing the inputs together. The output of cattle ranches is calves and yearlings; these animals are inputs in the production of meat, which is the final consumable product. Other inputs in meat production include corn, soybean meal and other feed grains. The economics of transporting inputs make it most cost-effective to ship the most valuable input (on a per-pound basis) to the location of the least valuable (or most bulky) input. Consequently, calves should be transported to the feed grains, so facilities that combine the inputs — called feedlots — are mostly located near the source of feeds, the Midwest. The output of feedlots — fed cattle — is the primary input for slaughterhouses and other meat-processing operations, so those facilities are usually located near feedlots in order to reduce the costs of shipping live cattle. In general, the structure of the cattle and meat industries developed to minimize total transportation costs (Clary et al. 1986).

These economic facts mean that the real value of a calf to a buyer is the price paid, adjusted for transportation costs. A cattle buyer for a feedlot is able to pay only up to whatever price translates into the maximum cost the feedlot can afford for their cattle input. The real value of that price depends upon who is responsible for paying the transportation costs incurred to get animals from the ranch to the feedlot. In most cases, calf sales contracts transfer ownership of the animals to the buyer at the time of the sale. This means the calves are "free on board" (FOB), from the rancher's point of view, as soon as the animals get on the truck. In other words, the buyer is actually paying the transportation costs. However, that lowers the maximum FOB price the buyer can pay to the rancher by the amount of transportation costs per pound, so that the total real value of the calf does not exceed the maximum affordable to the buyer.

The bottom line for cattle ranchers is that their price received depends on their location relative to the buyer's lo-

John Evans

UC researchers (left to right) Morgan Doran, Larry Forero and John Cronin demonstrate how weaned calves are processed under a Quality Assurance Program. Such "value-added" calves often receive higher prices.

Photos: Western Video Market

Data from Western Video market, based in Cottonwood, Calif., was used to analyze cattle market prices across the West. Auctions are conducted by satellite most months of the year.

cation. At any point in time, a buyer can offer a higher price to ranchers located closer to the feedlot. With most feedlots located in the Midwest, ranchers there are expected to receive higher prices, on average, than those received by ranchers in more distant locations. Therefore, California ranchers are disadvantaged relative to their Midwestern competitors, because they receive discounted prices for the same product in the current cattle-market structure.

Video market study

We conducted a study with recent data from Western Video Market to see whether the dynamic cattle market discounts the prices paid to ranchers in Western states, as predicted by economic theory, and still values several characteristics that earlier research found received price premiums. Western Video Market, based in Cottonwood, Calif., is operated in a manner typical of video sales operations. They hold auctions broadcast via satellite almost every month of the year (Western Video Market 2006).

Western Video Market provided us with anonymous information from 1,979 lots of steers sold in video auctions from 1997 to 2003. All lots had a flesh score of medium, a frame score of medium or medium-large, and average weights in the 500-pound to 625-pound range. This weight range was used to focus on the price effects of managing calves at weaning. The number of lots sold per year increased from 153 in 1998 to 397 in 2003. Average lot size increased from 130 head in 1997 to 146 head in 2003. In total, approximately 280,000 steers were included in our data.

We used data from video auctions because those sales operate much like a traditional auction, but have a much larger pool of potential buyers from across the country. Buyers watch the auction via satellite, so they can be anywhere. As each lot is being offered for sale, a prerecorded video taken by Western Video Market of the actual cattle is shown. Cattle sale prices observed in video auctions are often more indicative of "national" prices than local cash sales (Bailey et al. 1991). The cattle in our study were sold from ranches across most Western states (fig. 1). The data enabled us to analyze sales made at the same time at different locations.

Our analysis of price differences across locations was simplified by grouping the sales data into several market regions, based on the pooling and flow of cattle observed in those locations over recent years (Bailey et al. 1995) (fig. 1). The out-of-state regions (regions 3–6) are large, covering entire states, whereas California is divided into three regions (regions 10, 15 and 25) to permit the detailed analysis of local markets. In addition, region 20 covers

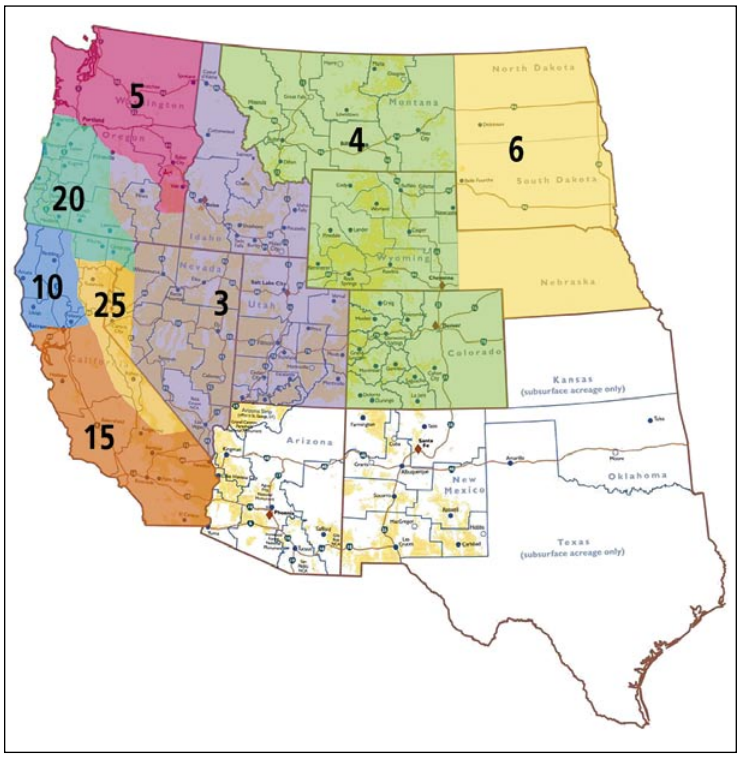

Fig. 1. Western and Midwestern market regions for video cattle sales.

TABLE 1. Average effects of factors on cattle prices, 1997–2003, and total discounts for all other regions

Factor	Price effect*	Significance†	Total discount‡
	$/cwt		*$/cwt*
Region 10 (NW Calif.)	–5.39	***	–6.66
Region 15 (S Calif.)	–5.20	***	6.47
Region 20 (W Ore., NW Nev., NE Calif.)	4.90	***	–6.17
Region 25 (E Calif., W Nev.)	–4.66	***	–5.93
Region 3 (SE Ore., Idaho, Utah, E Nev.)	–3.97	***	–5.24
Region 4 (Mont., Wyo., Colo.)	–1.27		
Region 5 (Wash., NE Ore.)	–5.25	***	–6.52
Region 6 (N.D., S.D., Neb.)	1.27	***	
Preconditioned	0.81	***	
Quality Assurance Program	0.92	***	
Implant	0.03		
Bunk broke§	–0.37		
Western Rancher's Beef¶	0.50		
Weaning, time since	1.27	***	
Natural beef#	1.60	***	
Forward contracting period	0.13		
Variability of animals in lot	–0.63	***	
Head number in lot	0.01	***	
Head number squared	0.00	*	
Weight (average/head)	–0.17	***	
Weight squared	0.00		
Breed**	a	mixed	
Trend over time††	b	***	

* Shows price average differences between the region indicated and region 4, the base. Negative numbers are discounts.

† Chi square for the random effects regression model is 1925.1; these variables are statistically significant (different than zero) when indicated by *, ** or *** (90%, 95% or 99% confidence level, respectively). A value with no asterisk is essentially zero, meaning there is no real price premium or discount.

‡ Total discounts between region indicated and region 6.

§ Bunk broke = cattle accustomed to eating out of a feed bunk.

¶ Rancher marketing cooperative with set standards for product sold by members.

Certified in an affidavit from the seller.

** Breeds received different average prices within a $1.50 range.

†† Four trend variables were used to account for the cattle cycle's effects on national market prices. Our data first trended downward, then upward, and then repeated that pattern from 1997–2003. All four trend variables were statistically significant.

TABLE 2. Regression results by market region, 1997–2003*

	Calif.		Region 20		Region 3		Region 4		Region 5		Region 6	
						$/cwt						
Preconditioned	1.62		2.06	***	2.03	***	0.86	**	0.59		1.06	*
Quality Assurance Program	–0.70		0.90		2.00	***	1.20		–1.48	*	1.04	
Weaning, time since	1.48	***	1.38	***	1.14	***	0.07		1.41	***	0.72	
Western Rancher's Beef	1.19		0.39		–0.89		NA		5.44	***	NA	
Bunk broke	0.07		0.39		0.38		4.06		3.13		–2.56	
Implant	–0.48		0.39		–0.05		0.24		–0.13		–0.21	
Natural beef	1.43		0.1		3.14	***	2.19	***	1.75		–0.19	
Variability	–0.25		–1.11	*	–0.77	**	–0.85	***	–0.51		–0.51	*
Forward contracting period	0.01		–0.39	***	–0.23		–0.02		1.17	***	–0.05	
Head number in lot	-0.01		0.02	*	0.01	**	0.01		0.02	**	0.05	***
Head number squared	0.00	*	–0.0001	*	0.00		0.00		0.00		–0.0001	***
Weight (average/head)	0.35		–0.09		–0.09		–0.16		–0.35		–0.40	**
Weight squared	0.00		0.00		0.00		0.00		0.00		0.00	*
Breed not known†	1.15		–3.27		NA		–0.95		2.67		–0.44	
Breed = Charolais	–3.28		0.78		1.24		0.57		0.06		–0.10	
Breed = English	–1.61		–2.04	***	–2.16	***	–0.16		–1.55	*	–1.54	*
Breed = Continental	1.24		–3.17	*	–1.24		–2.00		–2.60		–5.90	
Breed = mixed	–1.72		–1.91	***	–1.91		–2.51	***	1.66	**	–3.08	***
Trend over time‡	a	***	a	***	a	***	a	***	a	***	a	***
Constant	48.51		196.18	***	191.80	***	221.20	***	269.55	***	289.62	***
Adjusted R-squared	0.70		0.80		0.83		0.90		0.88		0.88	
Number of observations	174		337		400		514		248		30	

* Values are statistically significant (different than zero) only when indicated by *, ** or *** (90%, 95% or 99% confidence level, respectively).

† Angus calves were used as the base for evaluating breed effects.

‡ a = four trend variables were used to account for the cattle cycle's effects on regional market prices; all were statistically significant.

western Oregon, the extreme northwest corner of Nevada and the extreme northeast corner of California.

Other information available for each of the lots included characteristics of the animals, such as breed, and details about each sales contract. Random effects regression models enabled us to estimate the effects on the sales price of not only location, but also other variables that commonly influence cattle prices.

Price discounts in Western markets

Our study found that Western markets consistently received a price discount (table 1). We quantified the average amount of the price discount or premium received by cattlemen in each market region after accounting for the effects on prices from the other factors listed.

For example, in market region 10 (northwestern California), the regional price effect showed an average discount of $5.39/cwt relative to the average price received for sales in region 4 (Montana, Wyoming, Colorado), which was used as the base because that region had the most sales during the entire period. Therefore, to get the total discount compared to the Midwest, the average premium of $1.27/cwt received in region 6 (North Dakota, South Dakota, Nebraska) must be added, giving a total discount for region 10 compared to region 6 of $6.66. The total discounts for all other regions compared to average sales prices in the Midwest (region 6) are reported in the right-hand column of table 1. The regional results were consistent with the theory that the average price discounts will be larger the farther away the seller is from the Midwest.

California ranchers are disadvantaged relative to their Midwestern competitors, because they receive discounted prices in the current cattle-market structure.

The results for other factors listed in table 1 indicate how much the average price received was affected by the presence of a particular attribute across all regions during the entire period. For example, increasing the length of time since weaning raised average prices. For every 30 days in the length of time since weaning, the average price increased about 1.3 cents per pound. Also, calves that met the requirements of the natural beef program received a premium averaging $1.60/cwt.

We conducted the same type of regression analysis for each of the separate market regions to get more details about the effects on average prices from each of the factors, and found many differences across locations analyzed (table 2). This variability in results indicates differences in supply and demand in each market region.

The limited number of observations for region 10 led to weak statistical results, prompting us to combine the data for the three main California regions (10, 15 and 25) to get enough observations to generate reliable tests of the individual factors. By doing so, we got significant results for the variable "weaning, time since"; the average price received by ranchers in California was $1.48/cwt higher when they sold calves weaned at least 30 days (table 2).

Finally, location price discounts were evaluated by year to see if they changed over time (table 3). There were indeed differences in the average amounts from one year to the next in the seven sets of regression results. Those differences between years im-

TABLE 3. Regional price discounts by year*†

	1997	1998	1999	2000	2001	2002	2003
				$/cwt			
Region 10	–1.32	–3.44 ***	–4.13 **	–8.24 ***	–6.70 ***	–2.84 **	–4.66 ***
Region 15	–3.30 ***	–5.38 ***	–4.73 ***	–5.04 ***	–6.00 ***	–3.91 ***	–4.50 ***
Region 20	–5.13 ***	–4.83 ***	–4.21 ***	–6.64 ***	–6.44 ***	–2.35 ***	–4.58 ***
Region 25	–6.80 ***	–3.87 ***	–4.90 ***	–6.13 ***	–5.43 ***	–3.13 **	–4.58 ***
Region 3	–4.36 ***	–4.36 ***	–2.68 ***	–5.65 ***	–5.69 ***	–2.49 ***	–3.29 ***
Region 5	–5.73 ***	–4.81 ***	–3.50 ***	–6.54 ***	–7.30 ***	–3.94 ***	–4.41 ***
Region 6	0.66	0.83	1.40 **	1.49 **	–0.06	2.55 ***	1.67 ***
Adjusted R-squared	0.79	0.77	0.83	0.75	0.78	0.77	0.83
Number of observations	167	152	228	344	363	329	394

* Regression results show average price differences between the region indicated and region 4, which was used as the base. Negative numbers are discounts, positive numbers are premiums. Thus, region 6 had the highest average prices.

† These values are statistically significant (different than zero) only when indicated by *, ** or *** (90%, 95% or 99% confidence level, respectively).

ply that transportation costs are not the only source of the price discounts observed between the Midwest and other regions. These price differences across years also reflect differences in relative supply and demand in each location. However, the fact that the discount amounts are usually higher for regions farther from the Midwest supports the conclusion that transportation costs are a major source of the price differences observed.

Impact of value-added programs

We evaluated the impact of several "value-added" factors on the price received for calves. For our study, we defined preconditioning as animals that had received respiratory vaccinations prior to shipping. Those in Quality Assurance Programs (QAP) were handled according to specific guidelines (i.e., vaccinated in the neck). Implanting refers to whether or not the animal did or did not receive an implanted growth hormone. In addition, calves weaned earlier have a lower incidence of sickness.

We found that both preconditioning and the QAP received a small but statistically significant price premium, while implanting programs had no significant effect on the prices received by ranchers over the entire 1997 to 2003 period (table 1). However, many of the results varied between years (table 4). Clearly, there is much more to the story.

The explanation for the difference between results of earlier studies and our results is readily apparent. The cattle industry has responded to the market (fig. 2). In particular, less than 10% of the calves were sold as preconditioned during the period covered by earlier studies, but by 2001 the majority were preconditioned.

The catalyst behind this change is the dynamics of a competitive market: sellers respond to buyers' preferences. Buyers expressed a preference for preconditioned calves during the 1990s, but few sellers were aware of this change in demand at first, so few ranchers were supplying preconditioned animals to the market. Buyers' attitudes were typified by a feedyard manager in Nebraska who told a trade magazine in 1999, "I buy 4,700 calves per year, and cattle that are vaccinated are worth more to me than nonvaccinated cattle. In fact, I won't buy cattle that aren't preconditioned." Clearly, the message got out to ranchers, and starting in 2001 they were supplying the market with mostly preconditioned calves. In other words, the market niche became the market norm.

Our study found two characteristics that consistently received a price premium over the data period. First, increasing the length of time since weaning increased average prices. For every 30 days since weaning, the average price increased about 1.3 cents per pound (table 1). The premium varied from one year to the next (table 4), but was statistically significant each year beginning in 1998.

Second, calves that met the requirements of the natural beef program received a premium in each of the 5 years that sales of natural cattle were made in the video auctions, and that premium was statistically significant in 4 of those 5 years (table 4). To use the term "natural" on a food label, the U.S. Department of Agriculture requires that the product must be minimally processed, and cannot contain any artificial ingredients or preservatives. "Natural" calves have never received growth hormones, antibiotics or ionophores (organic compounds that facilitate growth). The amount of the price premium for natural beef was influenced by other factors such as breed and sale location (table 1). In our results, natural beef received a statistically significant premium in 4 of the 5 years, ranging from $1.11/cwt to $2.08/cwt (table 4). Over the entire 1997 to 2003 period, the average premium was $1.60/cwt (table 1).

In the future, the existence of natural beef premiums and their amount will depend upon the competitive response

TABLE 4. Price premiums for value-added calves*

Year	Preconditioned	QAP	Implant	Weaning, time since	Natural beef
			$/cwt		
1997	0.51	–0.33	0.29	0.64	
1998	0.86	0.02	1.03 ***	2.17 *	
1999	0.95 *	–2.28 **	0.13	0.80 **	2.08 ***
2000	0.02	1.15	–0.68 *	1.13 ***	0.52
2001	0.31	1.36 ***	0.11	1.29 ***	1.11 *
2002	0.66 **	0.30	–0.20	1.27 ***	1.20 **
2003	1.57 ***	1.73 **	–0.18	1.58 ***	1.84 ***

* Values reported here were estimated using regression analysis. Positive values are price premiums for the attribute, negative numbers are price discounts. These values are statistically significant (different than zero) only when indicated by *, ** or *** (90%, 95% or 99% confidence level, respectively). A value with no asterisk is essentially zero, meaning there is no real price premium or discount.

Steve Quirt/UCCE Marin County

"Natural" beef, such as, *above,* grass-fed cattle in Marin County, continues to receive a price premium.

Alison Van Eenennaam

Many Western growers have raised their average prices by implementing value-added programs such as increased weaning times and preconditioning. The future for Western ranchers may lie in responding to new market trends.

within the cattle market. If buyers continue to expand their demand for natural beef, price premiums may continue. However, as ranchers respond and provide increased supplies of natural beef to the market, the natural niche may become the norm and see its premiums competed away. During our study, natural beef sales were zero in 1997 and 1998, and steadily increased to 13% by 2003. Natural beef is still very much a niche market.

The same points can be made about the price effects of weaning-period length (fig. 2). The share of calves sold in the video market that were weaned more than 30 days was small in 1997 and 1998, but that share increased to around 30% for sales from 2000 through 2003. Cattle producers have responded to the market and are delivering more calves weaned for a longer period and, as a result, are receiving a price premium over the average price received for calves freshly weaned. However, the weaning niche could see smaller premiums if it grows to become a larger share of the market.

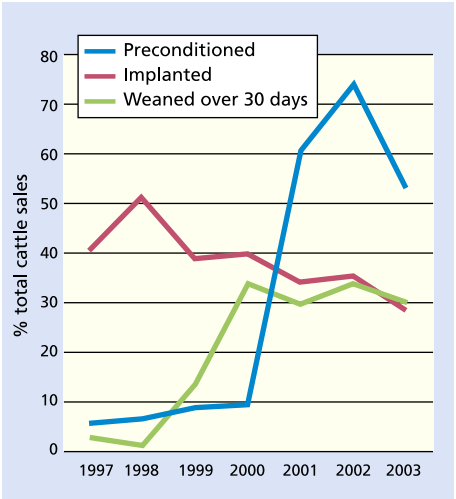

Fig. 2. Cattle preconditioned, implanted or weaned over 30 days as a percentage of total sales.

Market structure and price

In the future, the existence of location discounts and their amount will continue to depend upon the cattle-market structure. As long as most feedlots and meat-processing facilities are located in the Midwest, calves raised in California will be sold at a price discount and shipped out of the state.

This leaves ranchers in California and other Western locations with few ways to raise their average price received other than value-adding innovations, such as increasing the time between weaning and sale of a calf, or using "natural" production methods. These factors can result in higher average market prices (table 1). However, whether the costs associated with those factors are lower than the price benefits is a question each rancher will have to determine individually.

The irony of our general results is that beef producers were moving toward more standard use of preconditioning programs involving the use of "value-adding" medications, and now buyers are beginning to reflect consumers' preferences for cattle that are free of rancher interventions. Natural beef, free of hormones and antibiotics, is a move back to the simpler production practices of the past, as illustrated by the decline in the share of animals implanted (fig. 2). The Western cattle industry's future may involve discovering new market trends and quickly changing cattle management practices to produce a profitable niche product.

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Western Video Market. 2006. www.wvmcattle.com.

Information for Contributors

Editor's note: The following information is excerpted from California Agriculture*'s Writing Guidelines, which can be viewed or downloaded in full at http://CaliforniaAgriculture.ucop.edu. To receive a hard copy, contact* California Agriculture *at calagdesk@ucop.edu or (510) 987-0044.*

California Agriculture is a peer-reviewed journal reporting research, reviews and news in agricultural, natural and human resources. The authors are primarily, but not exclusively, faculty from the University of California and its Division of Agriculture and Natural Resources. It is published four times a year.

The first issue of *California Agriculture* was published in December 1946, making it one of the oldest continuously published land-grant university research publications in the country. It is also the largest-circulation publication of its kind (currently about 14,000 domestic and 1,700 international subscribers).

California Agriculture presents original, peer-reviewed research in a meaningful, real-world context. Our approach is geared to a well-educated, diverse readership (see Audience). We encourage authors to use direct language, to define technical terms and use interpretive tools such as glossaries and enhanced illustrations.

In the last 3 years, the rejection rate has run close to 25%. In addition, Associate Editors send back 7% to 10% of submissions for revision prior to peer review. Although most manuscripts make it through review, few manuscripts get through review "clean." As a rule, the Associate Editors and reviewers also require some revision before acceptance. We extensively edit all final manuscripts so that they are clear and accessible to our audience.

Peer-reviewed research

All published, signed papers are peer-reviewed.

Research articles are ideally 2,500 to 3,500 words including tables and figures, or four to six journal pages. Articles are expected to contain data representing a significant advance in one field; they may synthesize results from related experiments, presenting them in terms meaningful to both an interdisciplinary audience and educated lay readers.

Reviews are generally 3,500 words or less and analyze recent developments in research that significantly affect agricultural, natural or human resources in California. Readers should be able to learn what has been firmly established and what are unresolved questions or future directions for research.

Perspectives are review articles that interpret and analyze recent developments in research and public policy and express an opinion concerning the resulting impacts on California's agricultural, natural and human resources.

New pests and diseases are shorter review articles describing new pests and diseases of statewide significance. They are generally 2,500 to 3,000 words. Authors are expected to describe the host range, geographic range and important biological characteristics of the pest, citing the relevant literature. Articles must contain California data and describe expected impacts of the pest in the state.

Public policy research addresses broad public policy issues regarding agricultural, natural or human resources in California. We recognize that evidence can be qualitative as well as quantitative. In all cases, research should adhere to accepted standards of research methodology and statistical significance in the relevant discipline.

Surveys, case studies and program evaluations must also meet the standards for methodology and statistical significance in the relevant discipline. We encourage authors to include a comparative dimension in survey research, case studies and program evaluations. Readers should be able to understand California phenomena relative to broader scale, regional or national phenomena.

Manuscripts based on routine program assessments and feedback instruments do not generally pass peer review. Please contact the Associate Editor in your subject area or the *California Agriculture* staff before preparing program evaluations or survey research for submission.

Special collections and focus issues typically include both reviews and research articles on subjects that have stimulated significant interdisciplinary research and/or extension efforts at UC, and that have interest for a wide cross-section of the audience. Suggestions for coverage are welcome. Both solicited and unsolicited articles undergo peer review. To obtain *Guidelines for Special Collections and Focus Issues*, please e-mail janet.white@ucop.edu.

Sidebars are usually published within the text of signed manuscripts and illustrate or offer expanded discussion of a single aspect of the accompanying article. They are typically 600 to 1,000 words. Because of the brevity of sidebars, the conclusions drawn and assertions made must either be supported by the accompanying manuscript or by literature citations listed at the sidebar's conclusion. Like all signed papers, faculty-authored sidebars must undergo peer review, but they are evaluated for accuracy and balance rather than for the formal presentation of scientific data.

News sections of the journal

Most items in the news section are developed by editorial staff, based on UC research and extension activities; these include science briefs, research updates, introductions/overviews, outreach news and letters to the editor. News articles are not peer reviewed, but faculty sources review them for accuracy and balance of presentation. Non-peer-reviewed, faculty-authored articles in the news section include editorials, editorial overviews and outlooks. Suggestions for coverage are welcome.

Audience

California Agriculture is edited to reach a diverse, well-educated audience. Based on a 2003 reader survey to which 66% of our subscribers responded, 33% work in agriculture (25% in production or processing, 8% in agribusiness), and 31% are either faculty members at universities or research scientists. One-fifth or 19% work in government agencies or are elected office-holders. Of respondents, 87% are college graduates, and 55% of all respondents hold advanced degrees.

Peer review and editing

California Agriculture tries to maintain a balance between technical accuracy and a readable style to reach a diverse, well-educated audience. Language should be simple, direct, clear and concise. Technical terminology should be used sparingly, and clearly defined at the outset. Please review the full Writing Guidelines on our Web site for more detailed information about our requirements.

Each submission is forwarded to the appropriate Associate Editor, who makes an initial determination of its (1) scientific soundness and (2) suitability for *California Agriculture*'s audience. The Associate Editor then recommends two or three reviewers for double-blind peer review. After we hear from the reviewers, we send their recommendations to the author with the Associate Editor's instructions.

After the Associate Editor approves the revised manuscript, we will ask for the final version, including revised tables and graphs, images, author identifications and acknowledgements. The author will receive edited galleys — usually with numerous queries — for correction and approval before publication.

Illustrative material

California Agriculture prints high-quality color images with all articles, primarily using art supplied by the author. Digitized images, whether scanned from conventional prints or captured with a digital camera, must provide the resolution needed for our purposes. We prefer digital images be at least 300 dpi at 4" x 6" and saved as a TIFF or high-resolution JPEG file. Or, 35 mm color slides may be submitted, preferably good-quality originals. As a last resort, we can use good-quality color prints. We will return slides or prints after publication.

For more information about submitting images to *California Agriculture*, contact Davis Krauter at (510) 987-0046 or davis.krauter@ucop.edu.

Checklist for submission

California Agriculture is now managing the peer review of manuscripts online. Go to **http://repositories.cdlib.org/anrcs/californiaagriculture**. Click the "Submit article" button on the lower left-hand side of the screen, and follow the instructions. Those using the system for the first time will be asked to choose a password. Questions about online submission should be directed to Janet Byron at janet.byron@ucop.edu or (510) 987-0668.

Authors who prefer not to submit online should e-mail the manuscript to calagdesk@ucop.edu and janet.byron@ucop.edu.

Those who do *not* agree to the electronic transferal of their manuscripts should submit their cover letter and three copies of the manuscript to: Editor, *California Agriculture*, 1111 Franklin St., 6th Floor, Oakland, CA 94607-5200.

In preparing the manuscript, please:

- Double-space the whole manuscript, and include all tables, figures and captions at the end.
- Use a 12-point font, such as Palatino or Times New Roman.
- Leave margins that are a minimum of 1 inch.
- Include line numbering (per page) and page numbers.

All manuscripts must be accompanied by a cover letter. The cover letter should include:

- The names, addresses, e-mail addresses, telephone numbers and affiliations of all authors. The online sysyem will also prompt for this information at the time of electronic submission.
- The headline (title) of the paper and a statement of its main point.
- The total number of words (including text, references, and figure and table legends) in the manuscript.
- A statement that the material has not been published and is not under consideration for publication elsewhere. Those planning simultaneous submission of a manuscript with a technical or trade journal should disclose this information and/or contact the Managing Editor or Executive Editor.
- A statement specifying when the data was collected. If the final data was collected more than 3 years before submission, please state why they are timely and relevant.
- A statement permitting the electronic transferal of the manuscript to peer reviewers and the Associate Editor.
- A list of photographic illustrations, either available or suggested.

Conditions of acceptance

When a paper is accepted for publication in *California Agriculture*, it is understood that:

- Informed consent was obtained for studies on humans after the nature and possible consequences of the studies were explained.
- Care of experimental animals was in accordance with institutional guidelines.
- Photos depict situations that conform to relevant regulatory code, if any.
- Authors retain copyright but agree to grant to *California Agriculture* (and the eScholarship Repository and UC Regents) a nonexclusive license to publish the paper in print and online.
- Authors agree to disclose all affiliations, funding sources, and financial or management relationships that could be perceived as potential sources of bias.
- The paper will not be released to the press or the public before publication.

SIX DECADES OF . . .

California AGRICULTURE

60 years ago | 50 years ago | **40 years ago** | 30 years ago

Editor's note: In honor of our 60th anniversary, *California Agriculture* is publishing excerpts from past issues. Forty years ago, *California Agriculture* was still a black-and-white, monthly, 16-page magazine, with a circulation of up to 40,000 copies per issue. It featured short reports on a variety of agricultural and natural resource matters of importance to California.

Insecticides and beneficial insects in cotton fields

Evaluating the effect of pesticidal chemicals on beneficial insects is one of the research responsibilities of University of California entomologists. This progress report summarizes studies conducted on cotton during the past three years during which more than 15 toxicants were evaluated for their effect on common beneficial species.

A great many of the insects and insect-like species that frequent cotton fields are beneficial, since they prey upon the plant-feeding species. They are extremely helpful to the farmer in his battle to suppress and control the insects and mites that attack his crop. Modern insecticides have served an outstanding role in pest control. They have also served to remind us of the significance of naturally occurring beneficial organisms.

— T.F. Leigh, J.H. Black, C.E. Jackson and V.E. Burton (July 1966)

California Agriculture . . . 20 Years Later

The first issue of CALIFORNIA AGRICULTURE was produced and distributed in December, 1946 – 20 years ago. World War II had just ended and many in the armed services were still overseas waiting to return home. Farmers, like most other people, were beginning to catch their breath after living and working through four years of wartime economy.

Wartime research had unleashed the energy within the atom. Scientists (with the University of California in the forefront) had developed many new deadly weapons — both physical and chemical. Scientists within the California Agricultural Experiment Station . . . turned their attention to scientific discoveries made available by wartime research for the solution of the many problems of farmers, food processors, and distributors. Nerve gases developed for wartime use against human beings were found to be useful against plant pests, and radioactive isotopes made excellent tracers for studying problems connected with both plant and animal life. The publication of CALIFORNIA AGRICULTURE was started to report research progress made by these scientists and to get this information quickly to the farmer.

– C.F. Kelly, Director, UC Agricultural Experiment Station (December 1966)

Headlines from 1966:

Clipping tomato plants aids maturity and uniformity control for mechanical harvesting
— W.L. Sims (November 1966)

Chemical treatment of grape stakes may weaken young vines
— L.W. Neubauer and A.N. Kasimitis (July 1966)

For-hire trucking of exempt commodities by nonregulated carriers
— D.B. DeLoach and Walter Miklius (April 1966)

Research with biological control for house flies in Southern California
— E.F. Legner, E.C. Bay, H.W. Brydon and C.W. McCoy (April 1966)

Adjustable nozzles simplify irrigation of large container plants
— F.K. Aljibury (May 1966)

Productivity improvement with picker aids for grape harvesting – labor carriers, vine lifter, fruit handlers
— H.E. Studer, J.J. Kissler, Coby Lorenzen and R.R. Parks (August 1966)

Egg cooling rates affected by containers
— D.D. Bell and R.G. Curley (June 1966)

Effects of cold irrigation water on soil temperature and crop growth
— P.J. Wierenga and Robert M. Hagen (September 1966)

California Agriculture 60 years

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