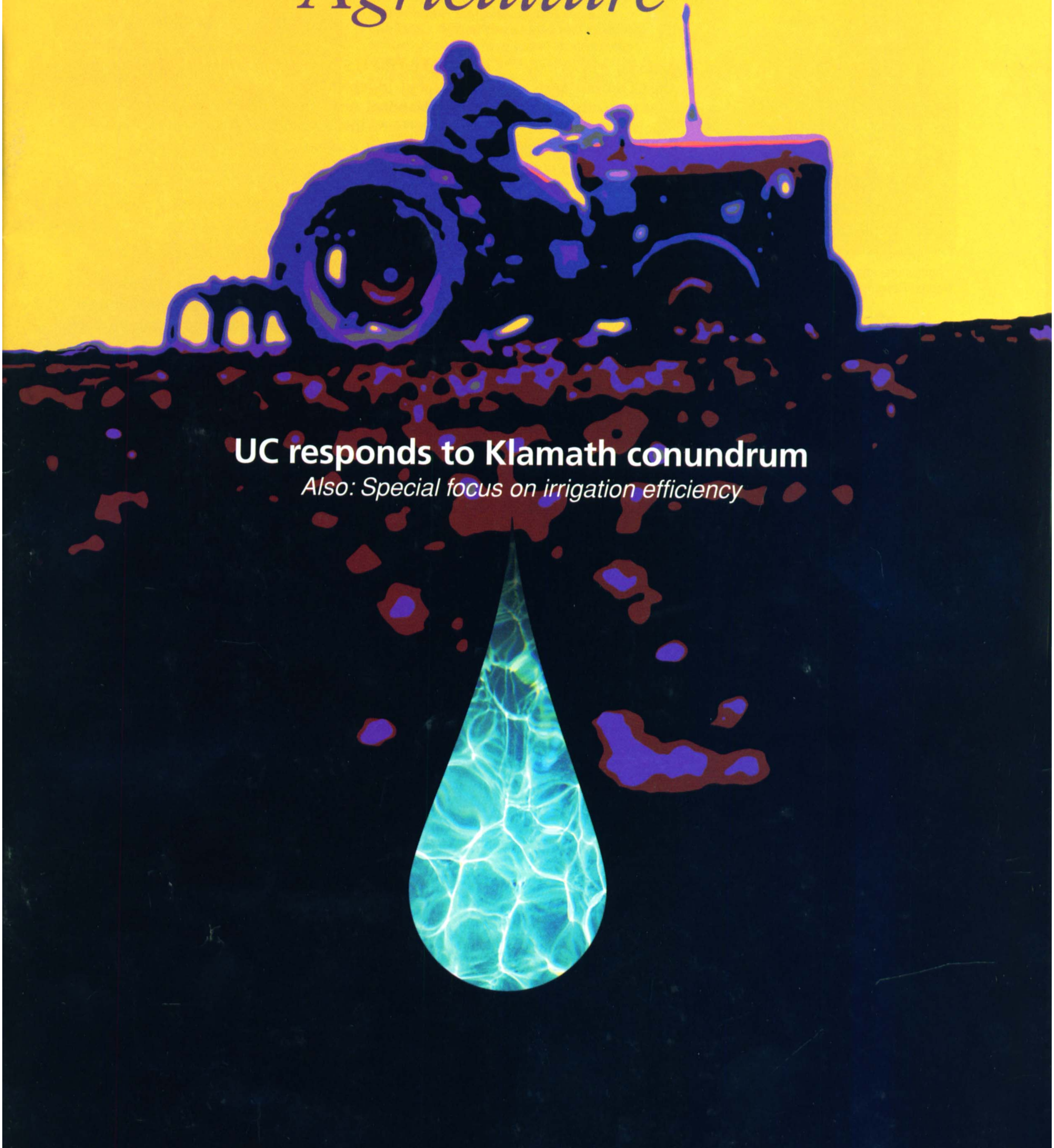
California Agriculture

JULY-AUGUST ■ VOLUME 56 NUMBER 4



UC responds to Klamath conundrum

Also: Special focus on irrigation efficiency

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

New realities for irrigated agriculture

Henry Vaux Jr.
Associate Vice President,
Agricultural and Natural Resources

The practice of irrigation has been indispensable in bringing California agriculture to the preeminent status that it enjoys today. Hydrologic variability, a two-season climate and sparse precipitation in arable areas all conspire against profitable and sustainable rain-fed agriculture in California. Thus, the production of high-valued fruit, nut and vegetable crops would simply not be possible without irrigation.

Despite its critical importance to California, there are signs that all is not well with irrigated agriculture. Increasingly, water traditionally allocated to agriculture is viewed as a potential supply for urban and environmental uses. It is also apparent that public policies governing water development are becoming less favorable to irrigated agriculture. These challenges likely mean that agriculture of the future will be different in some important respects from what it is today.

The intensifying competition for scarce water supplies almost certainly means that some agricultural water will be reallocated to urban and environmental uses and there will be somewhat less water available for agriculture. Other challenges will likely come from policies that will increasingly require those engaged in irrigated agriculture to operate in more environmentally friendly ways and to demonstrate the efficient use of public resources such as water, air and, in some cases, land.

Simultaneously, the economic circumstances of California agriculture will become more demanding as global markets increasingly drive the agricultural economy. As difficult as it may be, California growers will adapt to these new and rapidly changing circumstances as they have always done — through innovation and entrepreneurship.

The Division of Agriculture and Natural Resources (ANR) must play a large role in developing and disseminating the science needed to ensure that policies governing agriculture and the allocation of water are based on sound science. Additional research will be needed to provide the scientific basis for new technical and managerial innovations.

For example, where water is to be reallocated from agriculture to support environmental objectives, it will be important to avoid the problems and shortcomings that characterized the Klamath Basin reallocation in 2001. In the Klamath Basin, irrigation diversions were halted by the Department of Interior to provide additional water in-stream in response to concerns about population declines of several endangered fish species (see page 118). The decision to halt diversions was based in part upon a biological opinion prepared by the U.S. Fish and Wildlife Service. Subsequently, two independent peer reviews conducted by ANR and the National Academy of Sciences revealed that the science underlying this biological opinion was inadequate and concluded that it was based on oversimplified indicators of ecosystem health. The peer reviewers also noted that there was little or no actual information on the pertinent hydrological or biological processes or on effects of those processes on the fish of concern. The lack of science to support these kinds of decisions has been evident elsewhere in California and the West.

ANR faculty and other researchers from UC must redouble their efforts to develop a broad understanding of aquatic ecosystems if a repeat of the unfortunate circumstances last year in the Klamath Basin is to be avoided. What little is known is fragmented and piecemeal and there is a clear lack of knowledge about aquatic systems in a broad context. Additional research will be needed to help determine the water requirements of aquatic ecosystems and address issues related to the protection of rare and endangered species. In the absence of scientific information from comprehensive systems-based research, decisions to reallocate water from agricultural to environmental uses may have the twin drawbacks of doing significant economic harm to growers while failing to improve environmental conditions.

Regardless of how well we come to understand the science of aquatic ecosystems, the intensity of competition for water means that some reductions in agricultural water supplies are probably inevitable. Extensive research efforts must be mounted to develop the scientific knowledge needed for new and innovative technical and managerial irrigation regimes that will allow agriculture to adapt to diminished water availability. Some of the work reported in this issue of *California Agriculture* is illustrative of this type of research (see pages 121 through 138). For example, it is imperative to know how irrigation regimes vary with soil type, how different irrigation practices affect crop susceptibility to disease, and how complementary inputs such as land and energy can be managed to create efficient and productive systems.

But much more will need to be done. The potential of genetic modification to improve crop water use needs more comprehensive exploration. New knowledge will be needed if irrigation water is to be managed efficiently, to maintain productivity while limiting salinization, erosion and chemical contamination. ANR is committed to doing all that it can to provide the scientific knowledge needed for sound public policies to provide the means of adaptation to the new realities of irrigated agriculture.

California Agriculture

News and Peer-reviewed Research published bimonthly by the Division of Agriculture and Natural Resources, University of California
VOLUME 56, NUMBER 4

Executive Editor: Janet White
Managing Editor: Janet Byron
Art Director: Davis Krauter
Circulation Manager: John Fausone

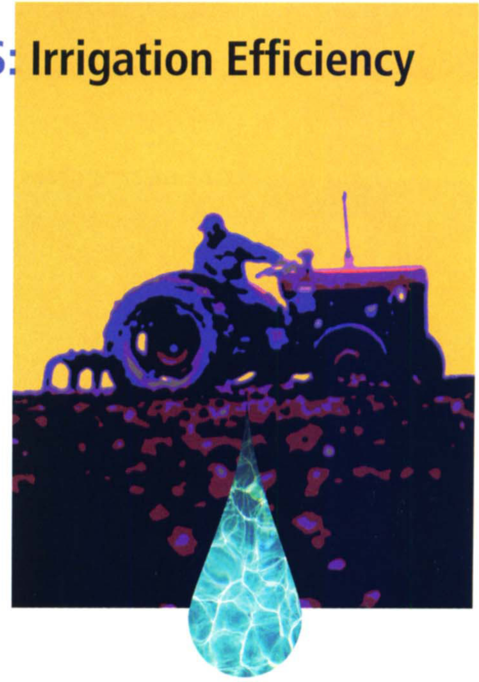
California Agriculture
1111 Franklin St., 6th floor
Oakland, CA 94607-5200
Phone: (510) 987-0044; Fax: (510) 465-2659
calag@ucop.edu
http://danr.ucop.edu/calag

Mailed at periodicals postage rates at Oakland, CA and at additional mailing offices. Postmaster: Send change of address "Form 3579" to *California Agriculture* at the above address. (ISSN 0008-0845)

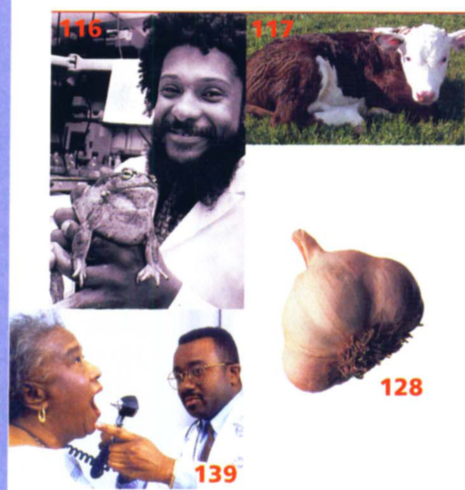
SUBSCRIPTION RATES: Free upon request in U.S.; $18 yearly outside the U.S. (check or International Money Order in U.S. funds payable to UC REGENTS). MasterCard/Visa accepted; requests require signature and card expiration date. Library subscriptions are free. Single copy price $4. For a change of address, send old label or subscription number.

SPECIAL FOCUS: Irrigation Efficiency

From the Klamath Basin to the Rio Grande, water is a much-disputed commodity in California. Increasingly, agricultural users must compete with environmental and urban needs for scarce water supplies. In this issue of *California Agriculture*, news and research articles focus on how growers and other water users can irrigate more efficiently and effectively. The cover story explores how UC has responded to the water crisis in the Klamath Basin, where hundreds of growers did not receive irrigation water in 2001 due to a severe drought and concerns about protecting three endangered fish species. Through research and outreach, the University plays a critical role in ensuring that precious water is utilized to the best advantage for wildlife, crops and people.



Cover graphic by Davis Krauter



News departments

Research articles

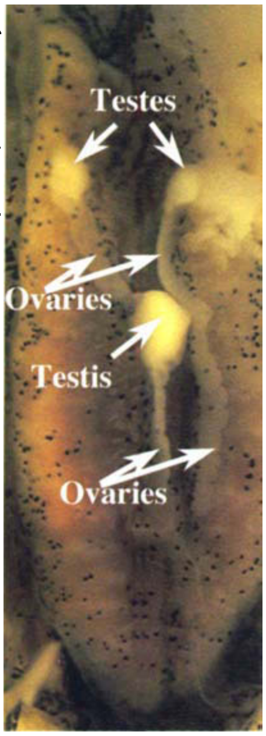
Atrazine scrambles frog sex organs

Exposure to atrazine demasculinizes tadpoles and can turn them into hermaphrodites with both male and female sexual characteristics, UC Berkeley scientists have found.

In the April 16 *Proceedings of the National Academy of Sciences*, developmental endocrinologist Tyrone Hayes and colleagues report that the widely applied herbicide also can lower levels of the male hormone testosterone in sexually mature male frogs as much as tenfold, to levels lower than those in normal female frogs.

In response to a new study by UC Berkeley scientist Tyrone Hayes, *above*, the U.S. Environmental Protection Agency may reconsider forthcoming rules on the use of atrazine.

Tyrone Hayes/UC Berkeley



Abnormal gonads in a male *Xenopus* frog are the result of exposure to the herbicide atrazine. The frog has become a hermaphrodite, with both male (testes) and female (ovaries) sex organs.

"Atrazine-exposed frogs don't have normal reproductive systems," Hayes says. "The males have ovaries in their testes and much smaller vocal organs," which are essential in calling potential mates.

The vocal chords of more than 80% of male frogs exposed to 1 part per billion (ppb) or more of atrazine were smaller than average; at concentrations of 0.1 ppb and higher, as many as 16% of the frogs had extra gonads.

Because it has been in use for 40 years in some 80 countries, atrazine's effect on sexual development in male frogs could be a factor contributing to the global decline of amphibians, Hayes says. More than 60 million pounds of atrazine were applied last year in the United States.

The laboratory tests used the African clawed frog *(Xenopus laevis)*, which is very sensitive to hormones that mimic its own sex hormones. If raised in a pond with the female hormone estrogen, for example, all *Xenopus* tadpoles turn into females. In the presence of male androgens such as testosterone, the frogs grow larger voice boxes.

"Atrazine probably does not have such severe effects on humans, because it does not accumulate in tissue and humans don't spend their lives in water the way frogs do," Hayes says. Nevertheless, the effects of atrazine on frogs could be a sign that the herbicide is subtly affecting human sex hormones.

The U.S. Environmental Protection Agency is currently re-evaluating allowable levels of atrazine in drinking water and the environment. Hayes found hermaphroditism in frogs at levels as low as 0.1 ppb, while draft regulations to protect aquatic life limit 4-day exposures to 12 ppb. Levels as high as 40 ppb have been measured in rain and spring water in parts of the Midwest, while atrazine in agricultural runoff can be present at several parts per million.

Hayes and his colleagues subsequently visited atrazine-contaminated ponds in the Midwest to see if such reproductive abnormalities occur in frogs in the wild. They turned up many native leopard frogs (*Rana pipiens*) with similar problems, and are now testing captured animals to determine whether the changes are due to atrazine. The researchers are also trying to determine how the abnormalities affect the frogs' ability to produce offspring. The National Science Foundation is supporting the studies.

Oral exposure to hormones "masculinizes" female finches

Female zebra finches that orally ingest the hormone estradiol benzoate as chicks develop "masculinized" brains and can sing if stimulated with testosterone as adults, UC Davis scientists have found.

Scientists discovered several decades ago that female finches exposed to estradiol — an estrogen commonly used in hormone replacement therapy — can sing like their male counterparts. Now UC scientists have found that giving doses of hormones to female finch chicks orally, a natural route of exposure to estrogenic chemicals in the environment, can induce "truly significant brain changes," UC Davis animal science professor James Millam says.

Exposure to estradiol benzoate also caused infertility in male finches and hindered the songbirds' ability to reproduce, according to studies by Millam and colleagues published in the December and April issues of *Hormones and Behavior*.

Male zebra finches exposed to estradiol benzoate, an estrogen, had a greater incidence of infertility and reduced reproductive ability.

"Our results indicate that songbird populations may be at risk if they are exposed to estrogenic chemicals as chicks," Millam says.

Hormones are powerful chemicals that regulate sexual development and reproductive ability. Synthetic hormones are leaking into the environment and may be having important impacts on wildlife, Millam says. For example, millions of women take estrogen in birth control pills and menopause treatments; estrogen is not broken down by water treatment and remains in sewage wastewater. More relevant to birds is the presence of hormone mimics in pesticides and industrial chemicals, which can be ingested by developing chicks.

The finches received a variety of estradiol doses, primarily at levels higher than those encountered in the environment (except the most polluted areas), although some reproductive impacts — such as increased egg breakage and male infertility — were identified at environmental levels. The U.S. Environmental Protection Agency funded the research.

Cloned calf "Rosie" is rosy

A cloned Hereford calf named Rosie is doing well after its birth at UC Davis on May 2.

The reddish-brown and white female is part of an ongoing study aimed at better understanding which types of adult cells are best suited for cloning cows. The researchers hope to improve the cloning technique, eventually using it to produce more healthful meat and milk products.

"We're encouraged that Rosie is feeding well and acting energetic like any other newborn calf," says Gary Anderson, professor and chair of the UC Davis animal science department. However, because young calves are especially vulnerable to respiratory, digestive and umbilical infections, scientists continue to watch her closely.

The calf was cloned from a follicle cell taken from the ovary of a 16-year-old, reddish-brown Hereford cow, and has the same coloring and markings as the cow from which she was cloned.

This is the second calf cloned and delivered at UC Davis. The first was born in August 2001 and died three days later due to multiple birth defects. Worldwide, an estimated 150 cloned calves have been born at about 10 laboratories.

The new calf is expected to remain at UC Davis for about 2 months, then go to a Northern California ranch where the cow from which she was cloned lives.

Cloning may someday enable scientists to produce replicas of individual animals that have valuable traits, such as cows whose milk is particularly nutritious. Cloning could also be used to genetically engineer cows and sheep that can produce pharmaceuticals in their milk.

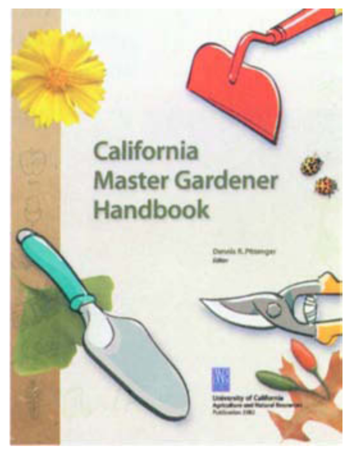
The current technology used to produce clones in the laboratory, called nuclear transfer, involves removing the nucleus (with its genetic material) from the unfertilized egg cell of one cow. Then a cell is taken from somatic tissue of a donor animal of the same species and placed next to the "empty" egg. In this case the donor cell was a follicle, supportive tissue in the cow's ovary.

Rosie weighed about 100 pounds at birth, a bit larger than the average 75 to 80 pounds usually seen in Hereford calves. Cloned calves are often unusually large, but this calf is considered within the normal range for her breed.

An electrical charge is applied, causing the two cells to fuse together. The fused egg is placed in a lab dish with the appropriate nutrients. Eventually the resulting embryo — which is a genetic copy of the animal that donated the nucleus — is transplanted into a surrogate mother.

Master Gardeners on page and screen

Published earlier this year, ANR's *California Master Gardener Handbook* is a runaway hit, quickly selling out its first print run (an additional 10,000 more copies have been delivered). "A new bible on the block for home gardeners," one garden editor wrote.

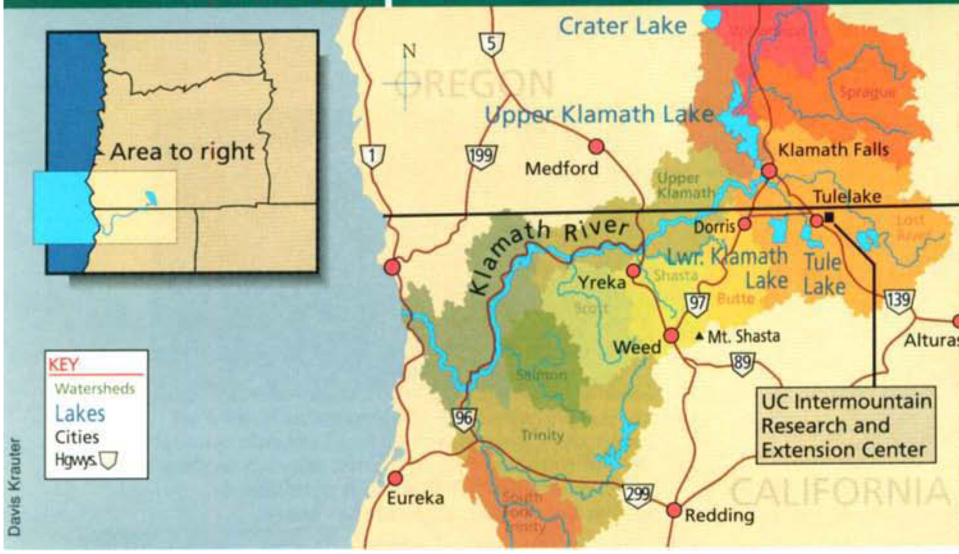


ANR's *California Master Gardener Handbook* is "a new bible" for home gardeners.

Now home gardeners have another opportunity to learn from UC Master Gardeners: UCTV will broadcast about 20 hours of the program's certification lectures this summer and fall. Broadcasts begin the last week in July and will include classes on integrated pest management, weed identification, the home vineyard and vertebrate pest control. UCTV is a systemwide channel with programming from all UC campuses, labs and ANR; it can be found on Dish Network Channel 9412 and various locations on cable. For information, go to www.uctv.tv.

The *California Master Gardener Handbook* (ANR Publication 3382) is 702 pages, with black-and-white photos, line illustrations and a glossary of terms. It includes chapters on individual crop cultural practices and, when applicable, nutrition of edible crops, plus chapters on related disciplines such as soil and water management, weeds and insect pests, and landscape plants and design. Copies cost $30, with discounts for ANR personnel and Master Gardeners. To order, go to http://anrcatalog.ucdavis.edu/ or call 1-800-994-8849 or (510) 642-2431.

— *Compiled from UC and other news sources*



Davis Krauter

Manu Esteve

During a severe drought — and in response to a lawsuit by environmental groups and commercial fishermen — federal regulators cut off irrigation water to several hundred growers in the Klamath Basin, *left*, in April 2001, in part to maintain water flows on the Klamath River for imperiled coho salmon, *right*.

Lessons flow from Klamath Basin water crisis

Water is flowing this summer, but the Klamath Basin continues to reel from the dramatic cutoff of irrigation water last year to hundreds of farmers.

Straddling the California-Oregon border, the high-elevation Klamath Basin is fairly remote and sparsely populated. But it made national headlines when a severe drought resulted in a decision by federal regulators on April 6, 2001, to stop the flow of irrigation waters that historically fed agriculture. The cutoff served to maintain flows in the Klamath River for coho salmon and to keep lake levels high for two endangered species of sucker fish in Upper Klamath Lake.

That's the day the phone started ringing off the hook at the UC Intermountain Research and Extension Center (IREC) in Tulelake, Calif., near the epicenter of the resulting uproar. On the other end of the line were desperate growers who needed answers on how to manage their dry fields, public agencies asking for information on improving irrigation efficiency, and scientists wondering whether they could conduct planned field studies.

"It was all consuming," says Harry Carlson, IREC superintendent and farm advisor. "The days were long." And more than year later, "it hasn't stopped," Carlson says, "although it's become a bit less intense."

UC scientists, advisors and outreach professionals continue to play a critical role in the Klamath Basin, providing science-based information, analysis and outreach for a variety of stakeholders, including farmers, fishermen, water managers, politicians, the media and government regulators.

At the same time, the IREC was dealing with a problem of its own: the cutoff of water to the 100-acre research plot leased for several decades from the Tulelake National Wildlife Refuge (see box).

The research program is on track this year, but Carlson estimates that he still spends half his time on activities related to last summer's irrigation cutoff, including serving on several regional committees and task forces. "We're looking at more long-term solutions," Carlson says. "If there's a silver lining to what happened, it's that there is almost a consensus across the stakeholders that we don't ever want to do it the way we did last year."

Century-old conflict

Last year's crisis has its roots in the century-old Klamath Project. In 1905, the federal government began draining much of the region's vast wetlands in order to create rich farmland. The land was offered to veterans of World Wars I and II, who were the nation's last "homesteaders" in the lower 48 states. The Basin's farmers today grow potato, alfalfa, horseradish and other crops, and raise livestock.

Six National Wildlife Refuges were also established in the Klamath Basin, which shelter millions of birds migrating along the Pacific Flyway and the largest wintering population of bald eagles in the continental United States. Nonetheless, coho salmon on the 254-mile Klamath River, as on many other Northwestern rivers, now face extinction. Two species of lake fish — which Native Americans had relied upon as a food source for centuries — are on the federal endangered species list: the Lost River sucker and the shortnose sucker.

With agricultural drainage providing much of the water for the wildlife refuges, "the connection between farming and the refuges is quite striking," says UC Davis agronomist Steve Kaffka.

For the past century, farmers, commercial fishermen, Native Americans, and wildlife and environmental activists have clashed over water, although the needs of agriculture were met most consistently. A drought in 1992 affected water deliveries to agriculture and initiated "the era of meetings and lawsuits," Kaffka says.

During the severe 2001 drought, the region received about half of its normal rainfall. A consortium of commercial fishermen and environmental groups sued the U.S. Bureau of Reclamation to limit water deliveries to farmers. Responding to the lawsuit and biological opinions issued by the U.S. Fish and Wildlife Service (FWS) and U.S. National Marine Fisheries Service (NMFS), the Bureau cut off irrigation water to most project growers to protect the fish.

While a subsequent moderately wet winter has eased the drought, environmental, tribal and fishing organizations have continued their legal efforts to maintain increased river flows and lake levels for fish. Faced with certain water shortages in the future, the situation remains tense.

Research informs Basin

Research is helping to provide critical information that the region needs to farm more efficiently and conserve and protect natural resources. Currently two dozen research projects are under way at the IREC, ranging from studies to develop improved potato, grain and alfalfa varieties to efforts to improve irrigation and pest management.

Water quality. For the past several years, Kaffka has been evaluating the effects of farming on water quality in the Klamath Basin, including surveying historic data to provide a baseline for comparison with more recent assessments. His team collected water samples every 10 days for several years, at 28 sites where water moves in and out of the Tulelake Irrigation District. Combined with earlier sampling efforts, they are now analyzing approximately 5,000 data points, the largest such data set ever collected in the region. "The data will be used to develop TMDL (total maximum daily load) rules for the Klamath River," Kaffka says.

Pasture and alfalfa irrigation. Steve Orloff, Siskiyou county director and farm advisor, and colleagues completed research in the late 1990s on the relationship among alfalfa and pasture irrigation, low flows in the Scott River and declines in anadromous fish populations. They found that there was potential to reduce irrigation, particularly on pastures, providing some potential for water conservation. Researchers are continuing to study the effect of the early-season irrigation cutoff on alfalfa yields. "Growers were surprised at how much yield they had with no water allocation," Orloff says.

Corinne Byrne

On March 29, 2002, the headgates at Canal A in Klamath Falls, Ore., were opened to provide irrigation water for Klamath Project farmers. Coastal commercial fishermen subsequently filed a lawsuit to maintain adequate flows on the Klamath River for migrating coho salmon.

Science peer review

In addition to conducting research, UC scientists have played an important role in reviewing the scientific foundations of government regulatory decisions. "UC scientists were brought in by outside people to take an objective look at the science and ask the hard questions, and see if the evidence was there to support various viewpoints," says UC Davis fish biologist Peter Moyle.

ANR peer review. In June 2001, state Assemblyman Dick Dickerson (R-Redding) asked the UC Division of Agriculture and Natural Resources (ANR) to peer review the FWS biological opinion on endangered suckers. The review, by four anonymous scientists, found that the science upon which the opinion was based was inadequate, but that the service did the best job it could with the information available.

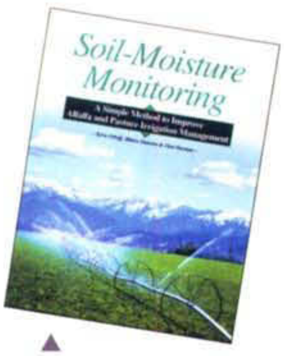
NAS report. In February 2002, the National Academy of Sciences (NAS) released an interim scientific evaluation of the FWS and NMFS biological opinions on the Klamath Basin's imperiled fish. While not directly questioning the decision to maintain minimum water levels at Upper Klamath Lake, the scientists found that the FWS data upon which that decision was made was not adequate.

"Based on existing evidence, the case wasn't strong at all," says Moyle, who represented UC on the NAS review committee along with UC Davis geologist Jeffrey Mount.

At the same time, the committee found that increasing flows to the Klamath River's main stem, as recommended by NMFS, probably would not

Between 1917 and 1947, thousands of veterans entered a series of lotteries for new agricultural lands created by draining much of Tule Lake under the federal Klamath Project. *Life* featured homesteader Dale Sprout and his family on a 1947 cover.

Upper Klamath Lake, *right*, is home to two native sucker fish; it flows into the Klamath River, *left*, where coho salmon spawn. Federal regulators must maintain a delicate balance between lake levels and river flows to protect all three endangered fish species.



UC advisors published a booklet on soil moisture monitoring targeted specifically to Klamath Basin growers, which provides a simple method for improving alfalfa and pasture irrigation management.

help juvenile coho salmon. The salmon are highly sensitive to water temperature, and the main water available was warm water from Upper Klamath Lake. Also, increasing flows down river would most likely require the same water that was claimed by FWS to keep lake levels high. "What's good for the suckers may not be good for coho salmon," Moyle says. "It's an ironic problem."

Moyle points out that while there may not have been perfect data to support the decision that was made, under the Endangered Species Act, "agencies are required to err on the side of species when they have doubts." The NAS is scheduled to finalize the review by early 2003.

Outreach and community building

UC scientists, outreach and extension personnel continue to look for ways to help the Klamath Basin community recover. For example, Kimberly Rodrigues, director of ANR's North Coast and Mountain Region, says that UC and Oregon State University (OSU) are contributing $40,000 each to promote community-building in the Klamath Basin.

OSU/UC report. In the difficult months after last April, researchers from OSU and UC collaborated on a baseline assessment of environmental, economic, institutional and social issues in the Klamath Basin. Goals of the forthcoming report include exploring water-allocation alternatives, proposing a research agenda and compiling resources for the region's stakeholders. "Our role is not to affect the outcome, but to provide science-based information," Rodrigues says.

"We are trying to provide a rapid assessment of the effects that the decision had, in what we considered a very large vacuum," says OSU professor Thomas Gallagher, who helped coordinate the report.

While OSU took the lead, UC contributors included Carlson, UC Berkeley professor Jeff Romm and graduate researcher George Woodward. In their policy assessment, the latter two wrote: "The problem is not caused by those whose interests are in dispute, but by broader institutional incapacity to create relationships that achieve equitable distributions in scarce times."

Outreach. Ongoing outreach projects have helped educate and inform Klamath Basin residents. In 1993, for example, UC extension advisors conducted training in principled negotiation for 20 of the Basin's agriculture leaders. "Farmer-citizens have to take time out from growing potatoes to advocate," Kaffka says. "Some of them became more effective at advocating their perspective."

UC advisors continue to offer a 4-day short course for ranchers and property owners on water quality in rangeland. ANR recently hired an anadromous fish specialist, Lisa Thompson, to work on inland fish species; she will be offering assistance in the Klamath region. Carlson and UCCE marine advisor James Waldvogel serve on a technical review team for the federal Klamath River Basin Fisheries Task Force,

▶ Kenneth Rykbost, superintendent of Oregon State University's Klamath Experiment Station, and Ronald Voss, UC extension vegetable crops specialist, show off an experimental potato variety harvested at the UC Intermountain Research and Extension Center.

Research delayed, cancelled by drought

For several decades, the UC Intermountain Research and Extension Center (IREC) has leased about 100 acres from the Tulelake National Wildlife Refuge for agricultural research. But as a result of last year's drought, irrigation was not allowed in the refuge and many research projects were delayed or postponed. Only about 7.5 acres was available for critical research projects at the center's headquarters, irrigated by an emergency well. From 20 to 25 full projects in a normal year, only about a dozen small projects were undertaken in 2001.

For example, UC Davis agronomist Lee Jackson lost a year of data, and several other cereal researchers had to curtail their work. Likewise, UC Davis vegetable specialist Ron Voss was able to plant on about half the space he was expecting, which "certainly impacted the quantity and quality of work that we were able to do." He planted 50% fewer varieties, and since the land at headquarters is not typical of actual growing conditions "the results we got weren't as useful to the growers," Voss says.

When the irrigation water stopped flowing, IREC had actually been in the process of preparing to move research to a new 120-acre site contiguous to the center. "Ironically, the justification to buy the land was the uncertainty of water availability," IREC superintendent Harry Carlson says. The irrigation cutoff gave center staff time to put in irrigation lines and prepare the site, and the new land is fully populated with field research this year. *—J.B.*

which annually allocates significant funding to research and fish recovery projects.

Research needs, long-term solutions

To inform future decision-making, Carlson identified several critical research needs for the Klamath Basin. First, better information is needed about the region's fish and their recovery. Regulators have focused on lake levels and river flows because they are manageable, but these "may not be the most important factors," Carlson says.

Second, better information is needed on the entire Klamath Basin ecosystem so that decisions can be made on a broader basis than what is good for single species. "Water being sent downstream for the salmon was being taken away from bald eagles," Carlson notes.

Third, more research should focus on restoration ecology of entire watersheds: "What happened here is an example of how badly we need that information," Carlson says.

Fourth, Carlson says interagency cooperation and coordination must be improved. In the Klamath Basin, as many as 30 federal, state, tribal and local public agencies have been working "almost at cross-purposes."

According to fish expert Moyle, one of the most important research needs is a standardized annual monitoring program for fish and water quality. "The data is so fragmented right now," he says.

The Klamath Basin situation is so complex and contentious that Moyle also recommends a comprehensive effort along the lines of CALFED, the federal-state interagency consortium that has been working since 1995 to resolve water-use conflicts in the San Francisco Bay-San Joaquin Delta region. In March 2002, President Bush appointed the Klamath River Basin Federal Working Group, which includes the secretaries of Agriculture, Commerce and Interior.

Proposed solutions to the Klamath Basin's water conundrum include a federal buyout of farmland from willing sellers, the promotion of irrigation improvements and less water-intensive crops, federal assistance to diversify the regional economy and the establishment of water banks. Environmental organizations are calling for a comprehensive wetlands and habitat restoration plan on the scale of the current effort to save the Florida Everglades.

Carlson believes that stakeholders in the region are moving toward a more coordinated response. "The crisis was a wakeup call that this is serious and decisions have wide-ranging impacts," he says. "The stakeholders are determined to develop more of a planned response so future water shortages don't come as such a drastic shock."

— *Janet Byron*

Salt tolerance of landscape species evaluated

In recent decades, signs touting the use of reclaimed or recycled water have popped up in many urban settings where landscape plants are watered, such as highways, parks and golf courses. Yet surprisingly, landscape management professionals "don't have much guidance on how safe recycled water is for the plants," says Lin Wu, UC Davis environmental horticulture professor.

The first wastewater treatment plant used solely for recycling water was built in San Francisco in 1932. Today, wastewater is recycled at more than 300 locations throughout California for agricultural and landscape irrigation, groundwater recharge and industrial uses. The California Water Resources Control Board estimates that by 2010, landscape irrigation will be the second largest use of reclaimed water, next to groundwater recharge.

Davis Krauter

Reclaimed water is increasingly used to water landscaping in golf courses, public highways and parks.

After most water treatment processes, Wu says, salt (NaCl) is the only remaining constituent that is potentially detrimental to landscape plants. During the mid-1990s, several cities and counties approached the UC Davis environmental horticulture department to request field evaluations of the salt tolerance of landscape plants.

In 1997, Wu, postgraduate researcher Xun Guo and Alameda County horticulture advisor Ali Harivandi initiated a series of studies. They grew common California landscape species in the field, containers and greenhouses; the plants were irrigated with water containing salt levels slightly above those found in most reclaimed waters, applied both by drip and sprinkler irrigation systems. The Elvenia J. Slosson Endowment Fund, Marin Municipal Water District and the city of San Jose supported the research program.

The properties of actual reclaimed water were provided by Marin Municipal Water District and South Bay Water Recycling of San Jose: average "real world" sodium concentrations range from about 160 milligrams per liter (mg/L) to 230 mg/L, and chloride ranges from 170 mg/L to 320 mg/L.

Species that were less tolerant to salty reclaimed water included liquidambar, *left*, and native California rose, *right*.

Salt tolerance of landscape plant species grown under sprinkler irrigation

Salt tolerance ratios:
Low = < 50% growth
Moderate = 50% to 90% growth
High = > 90% growth

Plant species	1,500 mg/L salt	500 mg/L salt
Abelia grandiflora 'Edward Goucher'	Low	Low
Acacia redolens (redolen acacia)	High	High
Albizia julibrissin (silk tree)	Low	Moderate
Arbutus unedo (strawberry tree)	Moderate	High
Buddleia davidii (butterfly bush)	Low	Low
Buxus japonica (Japanese boxwood)	High	High
Ceanothus thrysiforus (ceanothus)	Moderate	High
Cedrus deodara (deodar cedar)	High	High
Celtis sinensis (Chinese hackberry)	Low	Low
Clytostoma callistegioides (trumpet vine)	Low	Low
Cornus mas (Cornelian cherry)	Low	Low
Cotoneaster microphyllus 'Rockspray'	Low	Moderate
Escallonia rubra (escallonia)	Moderate	High
Euryops pectinatus (golden Marguerite)	Low	Low
Forsythia intermedia (forsythia)	Moderate	High
Fraxinus angustifolia (raywood ash)	Low	Moderate
Ginkgo biloba (ginkgo)	Low	Low
Jasminum polyanthum (jasmine)	Moderate	High
Juniperus virginiana 'Skyrocket' (juniper)	High	High
Koelreuteria paniculata (goldenrain tree)	Low	Moderate
Lantana camara (lantana)	Moderate	High
Liquidambar styraciflua (liquidambar)	Low	Low
Mahonia pinnata (California holly grape)	Low	Moderate
Myrtus communis (true myrtle)	Moderate	High
Nandina domestica (heavenly bamboo)	Low	Moderate
Nerium oleander (oleander)	High	High
Olea europea 'Montra' (dwarf olive)	High	High
Pinus cembroides (Mexican piñon pine)	High	High
Pistacia chinesis (Chinese pistache)	Low	Low
Pittosporum tobria (tobira pittosporum)	High	High
Plumbago auriculata (cape plumbago)	High	High
Prunus caroliniana (Carolina laurel cherry)	Low	High
Quercus agrifolia (coast live oak)	Moderate	High
Rhaphiolepis indica (indian hawthorn)	High	High
Rosa sp. (rose)	Low	Low
Sambucus nigra (elderberry)	Low	Moderate
Sapium sebiferum (Chinese tallow tree)	High	High
Washingtonia filifera (California fan palm)	High	High

Three salt levels were used in the studies: control (potable water containing about 80 mg/L sodium and 40 mg/L choride), low salt (500 mg/L salt) and high salt (1,500 mg/L). Plants were irrigated every third day with 1 inch of water.

For a nondestructive evaluation of salt stress responses, plant heights and canopy diameters were measured at the beginning and after 6 weeks of salt treatments. Visual symptoms such as chlorosis and leaf burn were recorded. Plant species were placed into three salt-tolerance categories for how well they grew (low, less than 50% growth; moderate, 50% to 90% growth; and high, greater than 90% growth).

All the plants irrigated by drip irrigation systems with either 500 mg/L or 1,500 mg/L salt exhibited normal growth, with most showing no foliar symptoms of salt stress. Apparently, the drip irrigation conducted by the study did not create soil salinity sufficient to induce salt stress in most of the plant species tested.

In California, however, "sprinkler irrigation is used for most landscape settings because it requires less maintenance and is less vulnerable to traffic," Wu says. Under sprinkler irrigation with low-salt water (500 mg/L), 21 (56%) species were salt tolerant, 7 (81%) were moderately tolerant and 10 (26%) were salt sensitive. In irrigation with high-salt water (1,500 mg/L), 12 (32%) species were salt tolerant, 8 (21%) were moderately tolerant and 18 (47%) were salt sensitive (see table).

Some of the best-performing species included Japanese boxwood, oleander, juniper, dwarf olive, Mexican piñon pine and California fan palm. Salt-sensitive species included rose, liquidambar, ginkgo and trumpet vine.

Wu says the studies found good agreement between the salt tolerance measured by actual plant growth and that measured by salt-stress symptoms. "The performance of landscape plants is judged by their appearance," Wu says. "So the tolerance of leaves to salt-laden water is a critical trait for selecting plants to irrigate with reclaimed water."

Demonstration gardens of landscape species irrigated with reclaimed water have been planted in San Jose and by the Marin County Water District. So far, no negative impacts on either the plants or the environment have been reported, Wu says.

The researchers recommend infrequent, heavy irrigation with reclaimed water, rather than frequent, light watering. Sprinkling should be done at night or in the early morning, and not on hot, dry, windy days. "Slowly rotating sprinklers that allow drying between cycles should be avoided as well," Wu says. — *Janet Byron*

Improving pumping plant efficiency does not always save energy

Blaine R. Hanson

Many California farms use pumping plants to facilitate irrigation. In order to save energy, the state has initiated a program to test and improve pump efficiency.

California's energy crisis in 2001 resulted in a state-funded program for testing irrigation pumps and improving pumping plant efficiency, with the goal of reducing energy use in California agriculture. Yet in reality, improving pumping plant efficiency may not actually translate into savings. To reduce electrical energy use, the kilowatt-hours must decrease because of fewer kilowatts or less operating time, or both. In order to evaluate the efficiency of various energy-improving adjustments, we studied several operations at pumping plants in the San Joaquin Valley. These included adjusting impellers, repairing worn pumps, replacing mismatched pumps and using more energy-efficient motors. We found that adjusting or repairing worn pumps may actually increase energy use, unless the operating time of the pumping plant is reduced. Multiple pump tests of a pumping plant are recommended, to help evaluate possible reasons for low efficiency. Pumping plant operators should also obtain the manufacturer's performance curves to use in the evaluation process.

In the late 1980s, the question "Does improving pumping plant efficiency save energy?" was posed to a group of growers and utility company representatives in Salinas. Most of the growers said no, while most of the utility employees said yes. Before this meeting, the utility company had spent a great deal of money to improve the efficiency of irrigation pumping plants in the Salinas area. The goal was to improve the ratio of pump output horsepower to input horsepower; in other words, to make the plants more efficient by pumping a greater volume or pressure of water while using the same or less energy.

Pumps are commonly used by California growers to pump water for irrigation. Deep-well turbine pumps are installed in a well for pumping groundwater. They consist of the pump housing or bowl, which contains an impeller (fig. 1). The impeller contains specially shaped vanes to channel the water. The impeller is attached to a shaft, which extends up to the ground surface and is connected to an electric motor or engine. Rotating the shaft, which occurs when the motor or engine is started, causes water to flow into the impeller. In addition, centrifugal or booster pumps generally are used to provide pressure (see photo, page 126). They are located at the ground surface and also consist of a housing, impeller and a short shaft attached to a motor or engine.

Pump efficiency is a measure of the amount of power produced by the pump per unit of input power. The power (rate of energy use) produced by a pump, called the water horsepower, depends on the pump capacity or flow rate, pressure developed by the pump, and the amount of pumping lift in the well (pumping lift is the elevation difference between the dis-

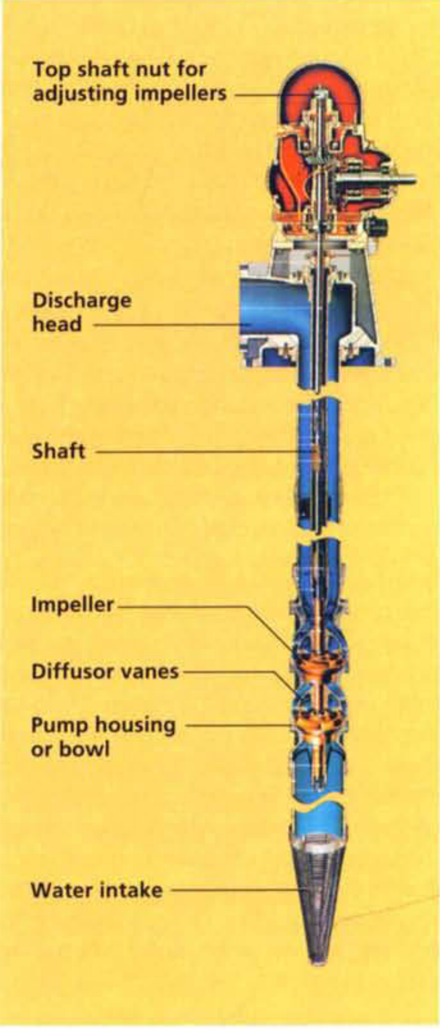


Fig. 1. Parts of a deep-well turbine.

TABLE 1. Effect of impeller adjustment on pumping plant performance

		Capacity (gpm)	Total head (feet)	Overall efficiency (%)	Input horsepower
Pump 1	Before	605	148	54	42
	After	910	152	71	49
Pump 2	Before	708	181	59	55
	After	789	206	63	65
Pump 3	Before	432	302	54	61
	After	539	323	65	67
Pump 4	Before	616	488	57	133
	After	796	489	68	144

TABLE 2. Effect of pump repair on pumping plant performance

	Before	After
Pumping lift (feet)	95	118
Capacity (gpm)	1,552	2,008
Input horsepower	83	89
Overall efficiency (%)	45	67

Calculating pump efficiency

The efficiency of a pumping plant is calculated as follows:

$$Eo = \frac{Q \times H}{3{,}960 \times IHP}$$

where *Eo* is the overall pumping efficiency, *Q* is the pump flow rate or capacity (gallons per minute [gpm]), *H* is total head or lift (feet), *IHP* is the input horsepower and 3,960 is a conversion factor, which converts the product of $Q \times H$ into horsepower. The total head is the sum of the pumping lift (elevation difference between the pump discharge pipe and the pumping water level in the well) and the discharge pressure head (discharge pressure in pounds per square inch [psi] multiplied by 2.31). The discharge pressure must be converted to feet of head to make it compatible with pumping lift, which is also in feet. (Note: a column of water 2.31 feet high creates 1 psi of pressure at its base.)

The input horsepower depends on the energy source. For electric motors, *IHP* can be calculated using

$$IHP = \frac{48.1 \times Kh}{t}$$

where *Kh* is the meter constant (stamped on the power meter faceplate) and *t* is the time in seconds for 10 revolutions of the meter disc. Newer power meters display the kilowatt demand of the electric motor. Kilowatts are multiplied by 1.34 to obtain horsepower.

The input horsepower of a diesel engine can be calculated by

$$IHP = 55 \times q$$

where *q* is the fuel consumption of the engine in gallons per hour. The fuel consumption can be measured by disconnecting the fuel line from the fuel tank, placing it into a container filled with a known volume of fuel and measuring the time it takes to fill the container with fuel. The discharge end of any bypass fuel line should also be inserted into the container. The input horsepower of a diesel engine may be three to four times that of an electric motor because of differences in engine efficiency. However, both are rated based on the brake or shaft horsepower: An electric motor rated at 100 horsepower produces the same power as a 100-horsepower diesel engine.

An inefficient engine may cause low overall efficiency even when the pump itself is efficient. Separating engine efficiency from pump efficiency requires specialized equipment. The efficiency of an electric motor tends to be relatively constant as long as the motor will run — unless the motor becomes severely underloaded, making separation easier. — *B.R.H.*

charge of the pump and the pumping water level in the well). The higher the efficiency, the more power that is produced per unit of input power.

Electricity users pay for energy based on the number of kilowatt-hours (kwh) consumed (plus fixed charges). The kilowatt is the power demand of the electric motor; 1 kilowatt equals 1.34 horsepower. The hours are the operating time of the motor. To reduce electrical energy use, the kilowatt-hours must decrease because of fewer kilowatts or less operating time, or both. Regardless of the claims about a proposed energy-saving measure, if the number of kilowatts or the operating time is not reduced, no energy savings will occur.

The 2001 energy crisis resulted in a state-funded program for testing pumps and improving pumping plant efficiency. The goal, of course, was to reduce energy use in California. Yet the grower response at the Salinas meeting suggests that improving efficiency may not actually translate into cost savings. This article discusses the reasons behind the growers' response.

Improving efficiency

Options for improving pumping plant efficiency include adjusting impellers, repairing or replacing worn pumps, replacing mismatched pumps, and converting to energy-efficient electric motors. The effect of these options on energy use was evaluated using data collected over the past 20 years from numerous pumping plant tests conducted by the author, utility companies and

TABLE 3. Pump test data of a mismatched pump

Measurement	Value
Pumping lift (feet)	113
Discharge pressure (psi)	50
Total head (feet)	228
Capacity (gpm)	940
Input horsepower	112
Overall efficiency (%)	48

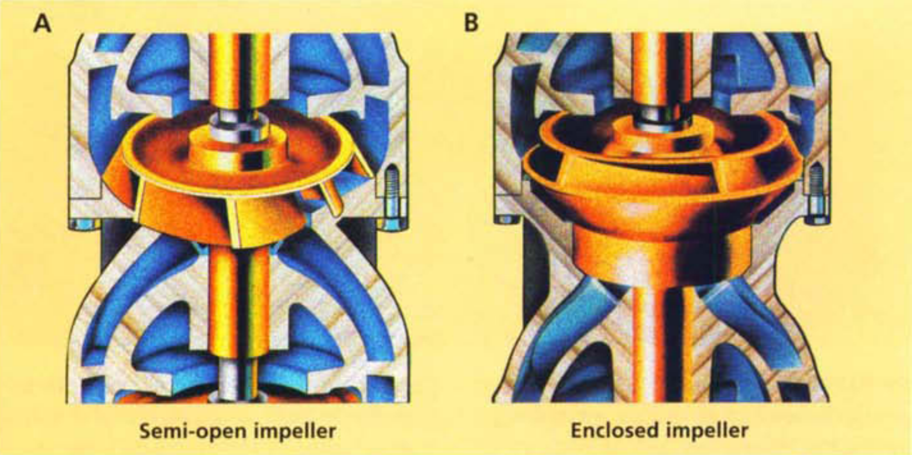


Fig. 2. To improve pump performance, semi-open impellers (A) can be adjusted, but enclosed impellers (B) cannot.

companies that install and maintain pumps.

Adjusting impellers. Maintaining the appropriate clearance between the bottom of the vanes of a semi-open impeller and the bowl housing is critical for efficient pump performance. Wear caused by sand in the well water can increase the clearance between the impellers and housing, and reduce pumping plant efficiency. Efficiency can be partially restored by adjusting the impellers. This involves slightly lowering the pump shaft and, in turn, the impellers, by rotating the nut at the top of the shaft (fig. 1). This adjustment will not work for enclosed impellers (fig. 2).

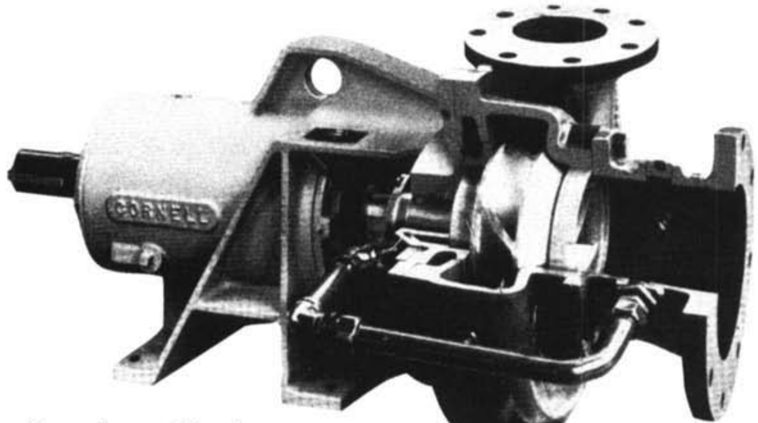
When we adjusted the impellers of four pumps, both pump capacity and overall efficiency increased considerably (table 1). Total head increased slightly, because pumping lift only contributed to total head (see box, page 124). However, for all four pumps, impeller adjustments increased input horsepower. Therefore, if the pumps are operated for the same amount of time after the adjustment (a common practice), energy use will increase. Energy use will decrease only if the operating time is decreased by pumping the same volume of water after the adjustment as before. For these data (table 1), the increase in energy costs ranged from 8.3% to 18.2% for the same operating time before and after adjustment. For tests 1, 3 and 4, the decrease in energy costs ranged from 12% to 22.4% to pump the same volume of water. For test 2, energy costs increased by 6%. In this case, the increase in pump capacity was insufficient to offset the increase in input horsepower because part of the increased pump output also contributed to increased total head.

Repairing worn pumps. Repairing a worn pump can increase capacity, total head and overall efficiency, as shown by the pump test data in table 2. However, for this data the input horsepower increased from 83 to 89. This behavior may be typical of many repaired pumps. A summary of 63 data sets of pump performance before and after repair shows increases of 39%, 0.5% and 33% in pump capacity, total head and overall efficiency, respectively (Hanson 1988). The small increase in total head occurred because pumping lift was the main contributor. However, the repair increased the input horsepower for 58% of the pumping plants, with an average increase of 17%. For these pumping plants, using the same operating time before and after the pump repair will increase energy use by 17%. However, pumping the same volume will decrease the average energy use by 22%. For many pumping plants, reducing the operating time may be necessary to realize any energy savings from pump repairs.

Operators of irrigation pumping plants commonly run repaired or adjusted pumps for the same amount of time after repairs or adjustments as they did before. Operating times are often based on the management and operating requirements of the particular irrigation system; as a result, it may not be possible to reduce operating time in many cases. The practice of not reducing operating times is what led to the growers' response in Salinas; it is possible that most irrigators were unaware of the need to reduce operating times and as a result were using more energy after their pumps were repaired.

Replacing mismatched pumps. A performance characteristic of deep-well turbine and centrifugal (booster) pumps is that as pump capacity increases, pump efficiency increases to a maximum and then decreases. New pumps should be selected to provide the desired flow rate and total head near the point of maximum efficiency, which minimizes the horsepower demand of the pump. Initially efficient pumps can become inefficient because of changes in operating conditions, such as different groundwater levels or alterations in discharge to pressurized irrigation systems, even though the pump is operating properly (no wear).

A pump operating properly but not near the point of maximum efficiency is said to be mismatched to the operating conditions. Used pumps are also candidates for being mismatched. To restore the pumping plant's efficiency, the mismatched pump must be replaced with one providing the desired total head and capacity near maximum efficiency. This change reduces



Worn impeller and a centrifugal pump.

the kilowatt demand of the pump and results in energy savings even if the operating time is unchanged.

A review of pump test data from a pump (table 3) revealed an overall efficiency of 48%. However, an efficiency of 57% was found by testing the pump under several different conditions. This relatively high efficiency suggested a mismatched pump. An analysis showed that replacing the inefficient pump with one producing the same output at an efficiency of 60% would reduce the input horsepower from 112 to 90, for a 19.6% reduction in energy use.

Using energy-efficient electric motors. Energy-efficient electric motors need less input horsepower than standard motors (table 4). Buying an energy-efficient motor for a new irrigation pumping plant is more economical than retrofitting an existing pumping plant. For example, an energy-efficient, 100-horsepower motor can cost $6,000, compared with $5,000 for a standard motor. The input horsepower of the energy-efficient motor will be 104 compared with 109 for the standard motor. At a typical cost of $0.1 per kilowatt-hour operating the pump for 2,000 hours per year will save $746, with a simple payback period of 1.3 years. The payback period for retrofitting, on the other hand, is 8 years.

Evaluating plant performance

Pumping plants should be evaluated every several years to determine the status of the pump and possible reasons for poor efficiency. Evaluating a pumping plant requires a pump test, during which capacity (flow rate), lift, discharge pressure and input horsepower are measured. The overall pumping plant efficiency is calculated from these data, and can then be compared with the standards for correcting electric pumping plants (table 5)(Hanson 2000).

Pump wear or a mismatched pump can cause poor efficiency. Likewise, repairing a mismatched pump may not improve efficiency. So how can one determine if a pump is mismatched or worn?

One approach is to conduct multiple pump tests, each under different operating conditions. These conditions can be imposed on a pump simply by partially closing a valve in the discharge pipe or changing the number of sprinkler pipelines or drip lines that are irrigated. An efficiency of about 60% or more for one of the tests indicates a mismatched pump under the normal operating conditions.

A second approach is to compare pump test data under normal operating conditions with the manufacturer's performance data. Manufacturers provide information for each pump on the relationships between capacity and total head, efficiency and brake horsepower. By comparing the total head of the pump test with the manufacturer's total head at the measured capacity, one can evaluate if a low efficiency is due to wear or mismatched operating conditions.

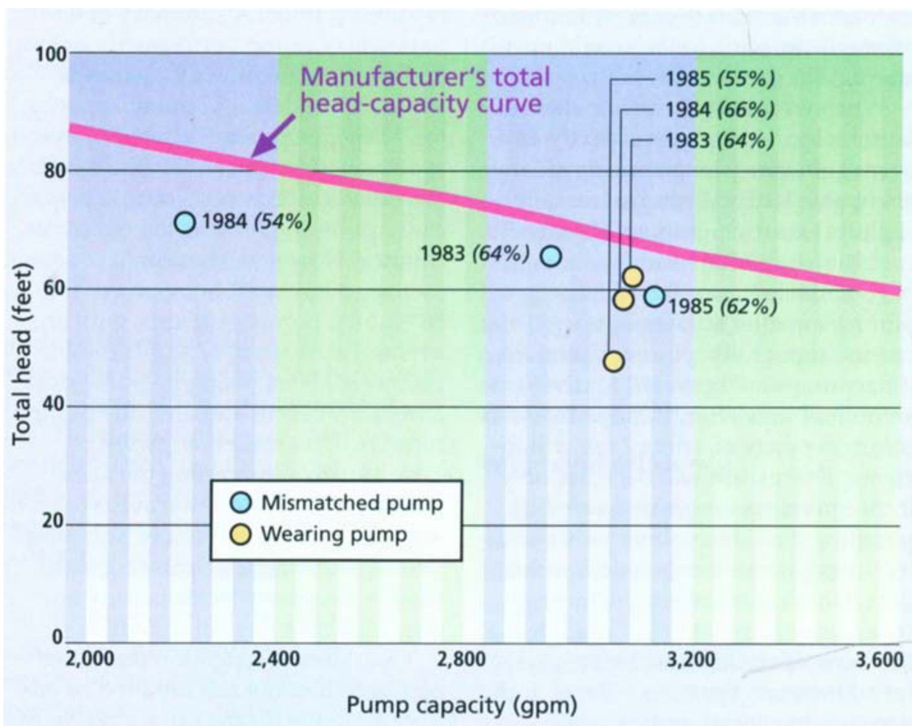


Fig. 3. Comparison of pump test data with manufacturer's total head-capacity curve of a mismatched pump and a wearing pump. Numbers in parentheses are pumping plant efficiency.

TABLE 4. Efficiencies of standard and energy-efficient electric motors

Horsepower	Standard	Energy efficient
	%	
10	86.5	91.7
20	86.5	93.0
50	90.2	94.5
75	90.2	95.0
100	91.7	95.8
125	91.7	96.2

TABLE 5. Efficiency standards for pumping plants with electric motors

Efficiency range	Suggested corrective action
Eo* greater than 60%	No action
55% to 59%	Consider adjusting impeller
50% to 54%	Consider adjusting impeller; consider repairing or replacing pump
Less than 50%	Consider repairing or replacing pump

* Overall pumping plant efficiency.

For example, a pump test conducted in 1984 showed an efficiency of 54% (fig. 3, mismatched pump). However, the deviation of the test point from the manufacturer's curve was about the same as that of the 1983 test point. The following year (1985), pump efficiency rebounded. This behavior suggests that the 1984 efficiency was due to a mismatched condition. The 1985 point, which shows efficiency similar to the 1983 test, verifies this. However, a second data set showed that the deviation between pump test data and the manufacturer's performance curve increased with time, indicating possible increasing pump wear (fig. 3, wearing pump).

Some caution is necessary in taking this approach. Poor-quality pump test data may prevent an accurate evaluation of the pumping plant. Cascading water in a well may prevent good measurements of pumping lift. Poor test conditions may also prevent good flow-rate measurements. The test section should have eight to 10 pipe diameters of straight pipe immediately upstream of a flow meter and two pipe diameters downstream to prevent errors due to excessive turbulence in the water. For a 10-inch-diameter pipe, a straight section 80 to 100 inches long is recommended. However, research has shown that propeller flow meters are less susceptible to large errors from turbulence caused by bends or elbows and checks valves upstream from the meter (Hanson and Schwankl 1998).

Energy savings

This series of studies shows that simply improving pumping plant efficiency does not guarantee energy savings. In fact, adjusting or repairing worn pumps may increase energy use unless the operating time of the pumping plant is reduced. Sometimes, adjusting the operating time still will not save energy if part of the increase in pump output contributes to a significant total head increase in addition to a capacity increase. With a higher flow rate, pumping plant operators can reduce operating time, with either less irrigation time per set or greater acreage irrigated per set. Opportunities for reducing the operating time will depend on site-specific conditions, such the irrigation method and its design and management characteristics. If reducing the operating time is not possible, the improved efficiency may result in more crop yield and revenue due to more water applied to a field. Both growers and others apparently did not recognize this fact at the Salinas meeting.

Multiple pump tests (at least three) of a pumping plant are recommended, to help evaluate possible reasons for low efficiency. Pumping plant operators should also obtain the manufacturer's performance curves to use in the evaluation process.

Adjustments to impellers, made by turning the nut at the top of the pump shaft, can improve pump efficiency. But that may not necessarily translate into energy savings, unless operating time is reduced.

B.R. Hanson is Extension Irrigation and Drainage Specialist, Department of Land, Air and Water Resources, UC Davis.

References

Hanson BR. 1988. Benefits and costs of improving pumping efficiency. Cal Ag 42(4):21–2.

Hanson BR. 2000. *Irrigation Pumping Plants.* UC DANR Pub 3377. 126 p.

Hanson BR, Schwankl LJ. 1998. Water turbulence disrupts accuracy of some flow meters. Cal Ag 52(1):25–30.

Garlic in clay loam soil thrives on little irrigation

Blaine R. Hanson ■ Don May
Ronald Voss ■ Marita Cantwell
Robert Rice

We conducted 4 years of irrigation experiments in garlic on the West Side of the San Joaquin Valley to determine appropriate irrigation frequency and cutoff dates as well as the effect of irrigation on yields for crops grown in sandy and clay loam soil. In sandy soil with the moisture content at field capacity prior to the rapid growth stage, yield was strongly dependent on applied water, and weekly irrigation was needed for maximum yield. In clay loam, yield did not depend on applied water because the garlic plants were able to extract sufficient soil moisture to offset deficit irrigation. Irrigation cutoff in both soils should occur by mid-May.

California supplies about 80% of the U.S. commercial garlic used for fresh-market, seed and dehydrated products. Within California, Fresno County in the San Joaquin Valley produces about 82% of the state's garlic crop, while the rest is grown primarily in Kern (11%) and Monterey (5%) counties (CDFA 2001).

Few studies have been published on water use and water management of garlic. One literature review of garlic concluded that (1) garlic has a rather sparse and shallow root system with roots limited to the top 2 feet of the soil; (2) best yields occur when the soil moisture content is maintained near field capacity; and (3) irrigation should cease 3 weeks before harvest to prevent rotting, discoloration of the bulb skins and exposure of outer cloves (Brewster and Rabinowitch 1990). Furrow irrigation is the most common in California garlic production, although sprinkler irrigation is sometimes used.

Irrigation practices by California garlic producers vary considerably, reflecting a lack of information regarding garlic's response to timing and the necessary amounts of irrigation. Our study investigated the effect of different approaches to irrigation on garlic in the San Joaquin Valley.

A look at water

We conducted 4 years of experiments at the UC Westside Research and Extension Center located in western Fresno County, with the California Early garlic variety, which is used for processing rather than sold fresh. All experimental plots were planted in mid-October and harvested in July. We used sprinkler irrigation to establish the stands.

Irrigation timing, 1997. In 1997, we investigated irrigation timing on garlic yield using a completely randomized-block split-plot design. The experimental design consisted of four furrow irrigation treatments on silt loam replicated six times as the main plots. Each 40-foot main plot contained four nitrogen fertilizer subplots, each with four 40-inch beds. Nitrogen applications were 100, 200, 300 and 400 pounds per acre. The irrigation treatments, which began in early March, were as follows: once a week with the last irrigation on May 9 (T1); once a week with the last irrigation on May 16 (T2); once every 1.5 weeks with the last irrigation on May 9 (T3); and once every 2 weeks with the last irrigation on May 16 (T4). For each plot, applied water and yield were measured. We measured soil moisture in three replications of each irrigation/fertilizer treatment using a neutron moisture meter calibrated for the soil type. (This device uses a probe con-

California supplies about 80% of the U.S. commercial garlic market, but little research has been conducted on appropriate water use and irrigation management for this important crop.

taining a radioactive source that is lowered into the soil using an access tube. The radiation emitted by the source is sensitive to soil moisture.) Measurements were made at 0.5-foot-depth intervals between 0.5 foot and 6 feet.

Irrigation cutoff dates, 1998. The 1998 experiment initially involved different water applications, using a randomized-block experimental design with six replicates on clay loam soil. But because of spring rainfall, irrigation did not occur until late April. As a result, the experiment was changed to investigate different irrigation cutoff times with subplots of nitrogen applications of 100, 175, 250, 325 and 400 pounds per acre.

The main treatments were irrigation cutoff dates of May 12, May 19, May 25 and June 1. Each subplot contained three beds with 40-inch spacing. The main plot length was 45 feet. Two beds were harvested for crop yield and quality.

Sprinkler line source, 1999. In the 1999 experiment, we used a sprinkler line source to determine garlic's response to applied water (Hanks, Keller et al. 1976). This system uses a single line with sprinklers spaced close together for good water distribution. The sprinkler line was 295 feet long with sprinklers (5/32 inch in nozzle diameter) spaced every 12 feet. Areas close to the line received more water than those farther away. We measured yield and amount of water applied, with distance from the sprinkler line.

The same fertilizer applications as in 1998 were applied to subplots (12 feet long) installed in a randomized-block design along both sides of the sprinkler line. We statistically analyzed the fertilizer effects using the method proposed by Hanks, Sisson et al. (1980). Soil texture at this site was clay loam between the soil surface and a depth of 5 feet with loam below.

Three transects of catch cans (6 inches in diameter), were installed in 12 beds on each side of the sprinkler line to measure applied water. These beds were harvested for yield. The sprinklers ran during the early morning hours when wind speed was minimal.

Two transects, each with six neutron-moisture-meter access tubes, were installed in every other bed on each side of the sprinkler line. Moisture contents were measured down to 3.5 feet at 0.5-foot-deep intervals, which according to 1997 results was deeper than any root growth.

Canopy coverage was determined at each access tube location using a Dycam infrared digital camera and its software, in order to describe the rate of crop growth. Canopy coverage is defined as the percentage of soil area shaded by the canopy at midday.

Sprinkler line source, 2000. The sprinkler-line-source experiment was repeated in 2000 on a coarse-texture soil. Soil texture was loam for the top 1 foot with sandy loam below. This source experiment was divided into four blocks, each containing three nitrogen fertilizer treatments (100, 250 and 400 pounds per acre). The plot was 23 feet long. In addition to the yield data, soluble solids (an indicator of garlic quality) were measured for selected plots. The data collected for 2000 were the same as in 1999.

TABLE 1. Results of 1997 garlic irrigation treatments*

Treatment	Irrigation interval	Cutoff date	Applied water (inches)	Yield (t/ac)	Soluble solids (%)
T1	1 week	May 9	14.0	9.5 b	
T2	1 week	May 16	17.2	10.2 a	42.0 a
T3	1.5 weeks	May 9	11.8	8.6 c	41.5 a
T4	2 weeks	May 16	14.3	8.6 c	

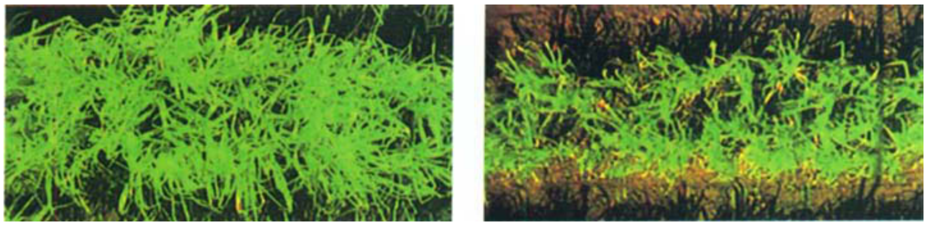
* Yields were averaged across all fertilizer treatments. Values with the same letter are statistically similar at a level of significance of 0.05.

Irrigation and garlic crops

Yield differences due to nitrogen treatments were not statistically significant in 1998, 1999 and 2000. In 1997, the yields of the highest nitrogen treatments were statistically significant from those of the two smaller treatments. However, these results may not be meaningful in light of results from the later 3 years, when no interactions occurred between nitrogen and irrigation.

1997 results. In 1997, T2 gave the highest yield, which was statistically different from yields of the other treatments (table 1). The yields of T3 and T4, significantly different from yields of T1 and T2, were the lowest. Less water was applied for T1 compared with T2 due to the earlier cutoff date, which affected yield.

Changes in soil moisture content between irrigation applications in 1997 occurred down to 2.5 feet, with little or no change below 2.5 feet (data not



Infrared photos show canopy coverage on garlic plants 5 feet, *left*, and 38 feet, *right*, from a sprinkler line, demonstrating the effect of decreasing applied water.

shown), suggesting little or no root activity below that depth. A decline in moisture content occurred for depths less than 2.5 feet during the measurement period.

1998 results. The 1998 results showed decreasing total yield with later cutoff date: The differences between the May 12 and May 19 yields and the May 25 and June 4 yields were statistically significant. No irrigation treatment effects on the percent of soluble solids were found. Lower yields occurred in 1998 compared with 1997 because of late rainfall and garlic rust, a fungal disease. In 1998, rainfall between early March and early June was nearly 4.4 inches.

1999 results. In 1999, yields and applied water were averaged across all nitrogen plots for each measurement distance from the sprinkler line. Garlic yield showed little or no response to applied water (fig. 1). The linear regression was not significant at a level of significance of 5%. The coefficient of determination was 0.014, indicating that little of the yield variability is explained by the variability in applied water.

Applied water decreased with distance from the sprinkler line on both sides in a fairly linear manner (fig. 2). Average water amounts ranged from 12.8 inches to 13.2 inches next to the sprinkler line, and from 3.2 inches to 3.4 inches at the farthest distance.

Unit bulb weight increased linearly with more applied water. The minimum average unit weight was 0.07 pound per bulb and the maximum was 0.12 pound per bulb. The coefficient of determination was 0.51, and the linear regression was significant.

The canopy coverage increased with time at all distances (fig. 3A). In the 160 days after planting, little difference in canopy coverage was found at each distance. After 160 days, the canopy coverage continued to increase, but only slightly at 38.1 feet. Average maximum canopy coverage, which occurred 200 days after planting, ranged from 73% to 78%, but was only 57% at 38.1 feet from the sprinkler line.

Changes in soil moisture were determined between early March, when moisture content was at field capacity, and early June. Maximum soil moisture content occurred in early March due to rainfall, while complete senescence occurred by early June. At 5 feet from the sprinkler line, a slight trend of decreasing soil moisture content occurred over time, for all depths except at 3.5 feet. Little change in soil moisture occurred at that depth. At 38 feet, soil moisture content decreased considerably over time at all depths. A response to irrigation occurred only at a 0.5-foot depth. The decrease in soil moisture content at 3.5 feet, from 50% to 35%, suggests that soil moisture extraction was occurring at greater depths. At this distance, the average change in soil moisture content during the measurement period was 2.3 inches per foot.

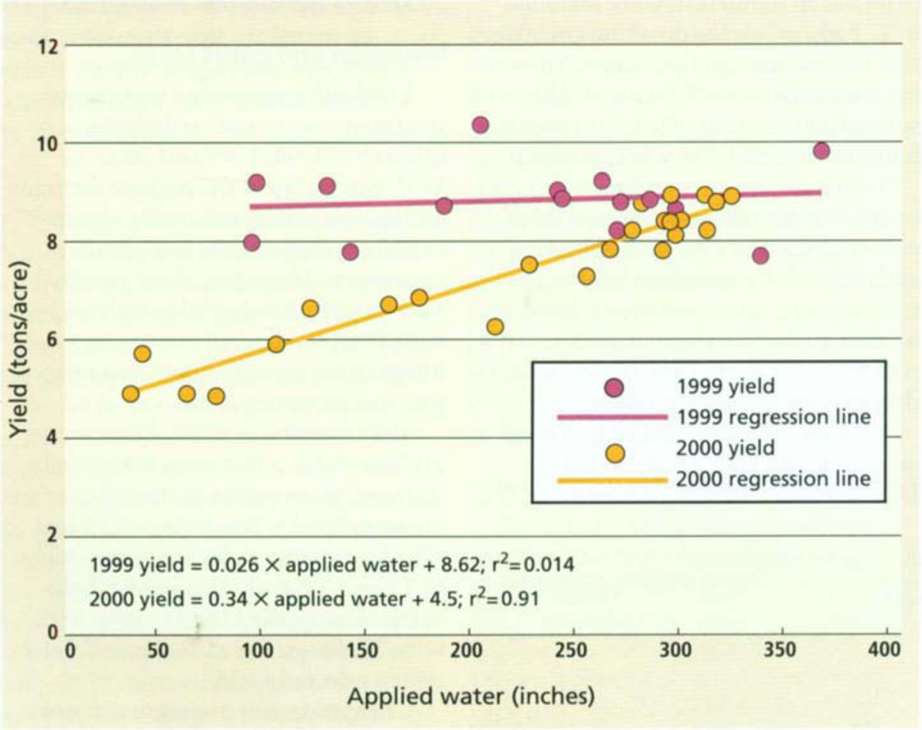


Fig. 1. Yield versus applied water for 1999 and 2000 sprinkler-line-source experiments. Equations describe the relationship between garlic yield and applied water.

2000 results. In 2000, garlic yield decreased with less applied water (fig. 1). The regression and coefficients of the linear regression equation were highly significant at a level of significance of 5%. The coefficient of determination was 0.91, indicating that almost all yield variability is explained by the variability in applied water.

Bulb weight increased linearly with increasing applied water, with a maximum average weight of 0.11 pound per bulb and a minimum of 0.06 pound per bulb. The coefficient of determination was 0.75; linear regression coefficients were statistically significant.

No significant trend was found between soluble solids and yield, or between soluble solids and nitrogen application. The average soluble solids content of 46 samples analyzed by a commercial processor's laboratory was 44.1%, with a standard deviation of 1.2%. In addition, no significant trends were found between dry weight and applied water, or between dry weight and nitrogen application.

Up to 16 feet from the sprinkler line, changes in applied water with distance were small, ranging from between 10.8 inches and 12.5 inches (fig. 2). Beyond about 16 feet, average applied water decreased fairly linearly with distance from the sprinkler line; the average water amounts of 1.2 inches and 1.4 inches were at the farthest distance.

Little difference in canopy coverage occurred with distance from the sprinkler line, up to 137 days after planting (fig. 3B). Thereafter, at distances of 18 feet or less, few differences between distances occurred over time, with maximum values ranging from 72% to 76% (200 days after planting). Beyond 18 feet, maximum canopy coverage values were less and occurred earlier. At the farthest distance, a maximum value of 57% occurred 171 days after planting.

Soil moisture content decreased over time at all distances (except 5 feet) and at all depths. The trend was less for depths greater than 3.5 feet. Little or no response due to irrigation occurred at depths greater than 2.5 feet. The average change in soil moisture content at the farthest distance was about 0.9 inch per foot.

Crop water use. The crop water-use values in these experiments do not include effective rainfall. Cumulative rainfall after early March was 0.6 inch in 1997 and 2000 and 0.9 inch in 1999. However, much uncertainty exists in estimating effective rainfall, which depends on factors such as amount, soil moisture depletion at time of rainfall, frequency of rainfall and absence or

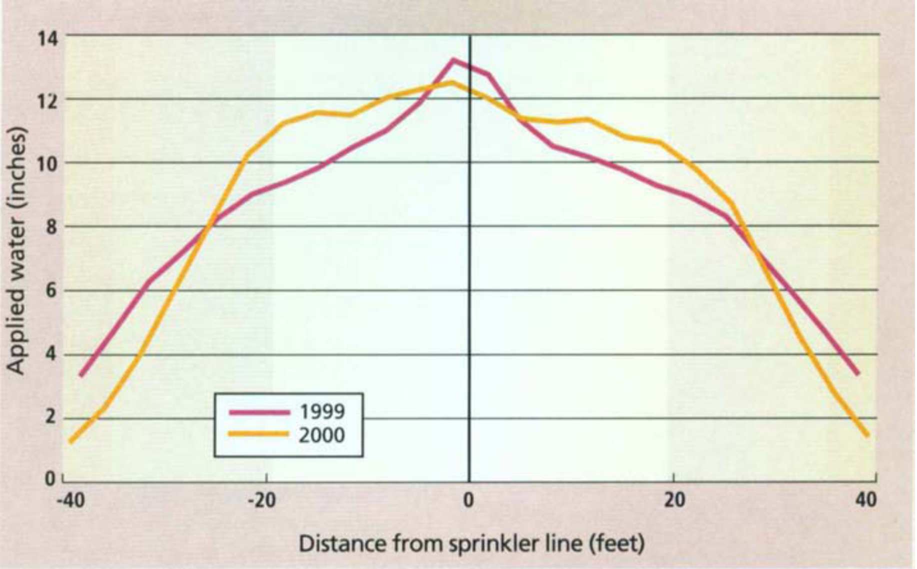


Fig. 2. Distribution of seasonal applied water for 1999 and 2000 sprinkler-line-source experiments.

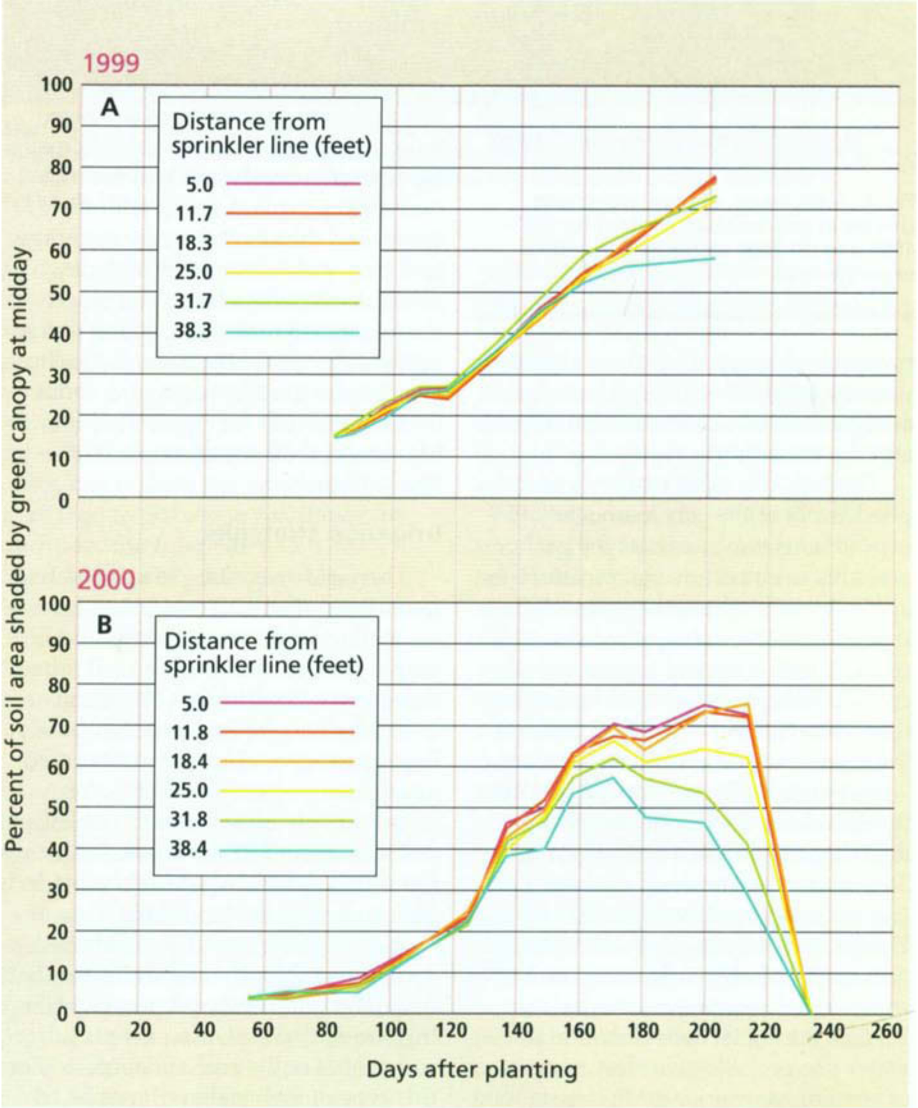


Fig. 3. Canopy coverage versus days after planting for (A) 1999 and (B) 2000 sprinkler-line-source experiments.

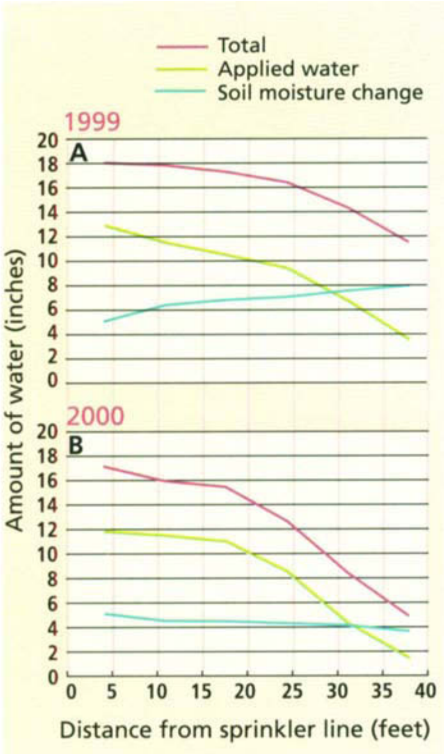


Fig. 4. Total water, applied water and change in soil moisture content for (A) 1999 and (B) 2000 sprinkler-line-source experiments.

presence of a crop. Effective rainfall was assumed to be negligible in these analyses because of the small amounts and the uncertainty.

The lack of a yield response to applied water at the clay loam site (1999 experiment) indicates that the garlic was able to substitute soil moisture for applied water where there was deficit irrigation. Although applied water decreased with distance, total water decreased only slightly for distances less than about 26 feet (fig. 4A). However, the change in soil moisture increased with distance. These data suggest that the garlic extracted moisture from depths greater than 4 feet. Beyond 26 feet, the total amount of water decreased considerably with distance. Except for the farthest distance, this decrease probably reflects the lack of soil moisture measurements below 3.5 feet. At the farthest distance, total water use probably was less because of smaller canopy size. Maximum total water use during the measurement period was about 17.7 inches.

The canopy coverage behavior indicates similar crop water use with distance, except at 38.1 feet, 160 days after planting. Canopy size determines the amount of radiation energy intercepted by the plant, and, in turn, the crop water use (Hsiao 1990). After 160 days, crop water use at 38.1 feet would be less compared with the other distances because of the smaller canopy size. Nevertheless, this potential reduction in water use had no effect on garlic yield.

Total water use in 2000 decreased with distance (fig. 4B). The change in soil moisture content also decreased with distance. Soil moisture was insufficient in the sandy soil to offset the decreasing applied water with distance, and thus both canopy coverage and crop yield decreased with distance. As stated earlier, the average change in soil moisture content at the farthest distance was about 2.3 inches per foot for the clay loam and about 0.9 inch per foot for the sandy loam. Maximum total water use in 2000 was about 17 inches.

Irrigation strategies

The yield responses to applied water suggest that different irrigation water management strategies should be employed based on soil type. For both line-source experiments (1999 and 2000), the soil moisture content was at field capacity at the start of the rapid growth stage. Sprinkler irrigation (commonly used for stand establishment) and rainfall should replenish the soil moisture by late February. Irrigation should start in March.

For clay loam soil, the yield response to applied water indicates that irrigation amounts, and possibly timing, are not critical, assuming a full soil profile at the end of February. For this type of soil, yield will not be reduced when irrigation amounts are less than the potential crop water use. This approach may improve irrigation efficiency, stretch limited water supplies during a drought and reduce subsurface drainage.

Sandy loam soil requires weekly irrigation in amounts sufficient to replenish soil moisture between irrigations and prevent yield loss. The last irrigation should occur by mid-May for California Early variety. The amount used by the crop starting in early March should be about 17 inches to 18 inches plus that needed for irrigation system inefficiencies. Based on the 2000 results, reduced water applications should not adversely affect the soluble solids or dry weight of garlic crops.

B.R. Hanson is Extension Irrigation and Drainage Specialist, Department of Land, Air and Water Resources, UC Davis; D. May is Farm Advisor (emeritus), UC Cooperative Extension, Fresno; R. Voss is Extension Vegetable Crops Specialist, and M. Cantwell is Extension Postharvest Specialist, Department of Vegetable Crops, UC Davis; and R. Rice is Agronomist (retired), Rogers Foods, Modesto.

References

Brewster JI, Rabinowitch HD. 1990. Garlic agronomy. In: *Onions and Allied Crops. Vol. III. Biochemistry, Food Science, and Minor Crops.* Boca Raton, FL: CRC Pr.

[CDFA] California Department of Food and Agriculture. 2001. Agricultural Statistical Review. In: CDFA Resource Directory 2000. Sacramento, CA. 110 p.

Hanks RJ, Keller J, Rasmussen VP, Wilson GD. 1976. Line source sprinkler for continuous variable irrigation-crop production studies. Soil Sci Soc Am J 40:426–9.

Hanks RJ, Sisson DV, Hurst RL, Hubbard KG. 1980. Statistical analysis of results from irrigation experiments using the line-source sprinkler system. Soil Sci Soc Am J 44:886–8.

Hsiao TC. 1990. Plant-atmosphere interactions, evapotranspiration, and irrigation scheduling. Acta Horticulturae 270:55–66.

Buried drip irrigation reduces fungal disease in pistachio orchards

David A. Goldhamer
Themis J. Michailides
David P. Morgan

Alternaria late blight, a fungal disease affecting both leaves and fruit, can lower the quality of pistachios and reduce grower profit. High humidity in orchards increases the magnitude and severity of the blight infections. One cause of high orchard humidity is the evaporation of water from the soil surface, which in turn is enhanced by irrigation systems that wet the surface. In this study, we tested the use of buried drip irrigation, which reduces orchard floor wetting, to see how well it controlled the disease. When compared with a traditional flood irrigation system, the buried drip system reduced orchard humidity and dew duration and increased temperature. This significantly reduced leaf symptoms of the disease and fruit infection at harvest. Additionally, more shells split open with the buried drip method, resulting in a higher yield of marketable pistachios.

Humidity in pistachio orchards increases the magnitude and severity of Alternaria late blight, a fungal disease that causes defoliation, shell staining, mold contamination and reduced shell-splitting. Flood irrigation, *above*, can contribute to high humidity in orchards.

Alternaria late blight (ALB) is difficult to treat in California pistachio orchards. The pathogen, *Alternaria* spp., infects both leaves and fruit, causing early defoliation, severe brown-black stains on the shells, and mold contamination of the shells and kernels. In addition, fewer shells split open. The closed shells combined with staining can result in losses of as much as $1,000 per acre. Other damage from ALB includes poor flavor and possible mycotoxin contamination.

Generally, *Alternaria* diseases — which affect many agricultural crops including carrot, cotton, tomato, almond, citrus and pear — are difficult to control. Significant control of *Alternaria* has only been achieved in the last few years with repeated application of azoxystrobin (Abound), which is a member of the new class of strobilurin fungicides. However, repeated fungicide sprays increase costs, can pollute the environment and may lead to pathogen resistance. In addition, the fungicides that are available to pistachio growers are limited and their efficacy is questionable (Michailides and Morgan 1993). Therefore, alternative disease management approaches are needed.

Severe cases of ALB have been identified in irrigated orchards where harvests are delayed and humid days and nights prevail from late August through October. The disease on pistachio leaves and fruit (sold in the shell as in-shell kernels or "nuts") manifests earlier in orchards with flood irrigation than in those with drip/microsprinklers or sprinklers. However, propagule (spore inoculum) populations of *Alternaria* spp. increase from early August to mid-September regardless of the irrigation system. We define this stage of the season as the critical period for disease development. This period is characterized by increased relative humidity, the onset of dew formation on the leaves and the appearance of the first leaf symptoms of the disease. Control measures should be conducted before this critical period (Michailides et al. 1991).

Orchard humidity depends not only on irrigation frequency but also on the length of time that the soil stays wet. Flood systems, especially when they are used in soils with poor infiltration rates, can result in high humidity for days following irrigation. Although they wet a limited soil area, drip irrigation systems must be operated frequently (every day or two), eliminating the possibility of increasing the irrigation interval. Buried drip irrigation was developed in part to reduce or eliminate surface evaporation (E), one of the two components of orchard evapotranspiration (ETc), and, in turn, save water. Steady improvements in buried drip irrigation technology, including limiting root intrusion and other plugging problems, have made commercial installation feasible.

Severe ALB in Kings County orchard

A commercial, flood-irrigated pistachio orchard in Kings County was suffering from severe ALB damage during the mid-1990s. The orchard's heavy soil, coupled with its poor infiltration rate, caused water to stand for 48 to 72 hours and led to a high level of humidity in the orchard. The grower had tried all conventional approaches for reducing the time the soil surface was wetted, including applying gypsum to improve infiltration and converting from flood to microsprinklers in some of his orchards. These measures had not appreciably reduced the incidence of ALB. The grower was spending a great deal of money on an intensive fungicide program for ALB but still experienced severe infections and associated shell staining, particularly when the crop was harvested late. We were asked to participate in a 2-year study to determine if buried drip irrigation could reduce orchard humidity and dew formation, control the disease and improve crop productivity without fungicide treatments.

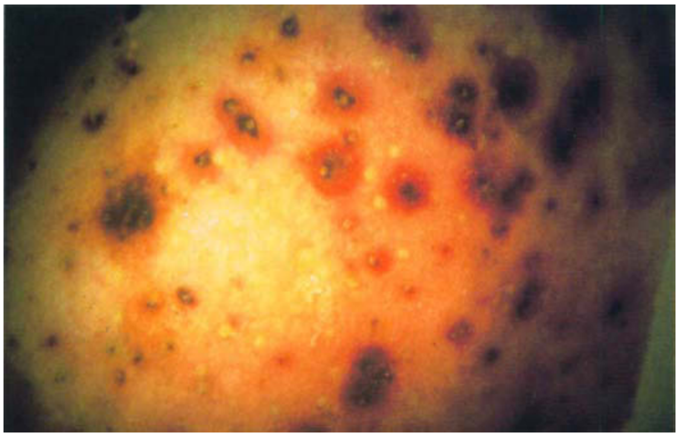
Installing the tubing. One of the problems associated with buried drip irrigation is unintended surface wetting. Sometimes known as "surfacing" or the "chimney effect," it occurs when water moves upward from the emitters through the soil that was disturbed during the tubing installation. This problem defeats the primary benefit of buried drip — a dry soil surface. We conducted preliminary tests in the orchard to determine how deep the tubing would have to be placed to avoid this problem. A depth of 30 inches resulted in the least amount of surface wetting and was chosen as the target depth for installation.

We divided an 80-acre, 12-year-old, flood-irrigated orchard (with 17-foot-by-19-foot tree spacing) into 12-row plots. A randomized, complete block design was used with five replicates of the flood and buried drip irrigation treatments. We installed buried drip irrigation by shanking in 5/8-inch nominal polyethylene tubing (Drip-In Irrigation Co., Fresno) with 0.5-gallon-per-hour, Treflan-incorporated emitters (Geoflow Inc., Sausalito) placed in the line every 45 inches. The design called for two drip lines per tree row, each spaced 4 feet from the tree row. The largest crawler tractor that would fit in the orchard, a Caterpillar D7, was equipped with two specialized steel shanks and tubing spools mounted on the tool bar. Because of the dense soil, it was necessary to make two passes with the tractor and shanks prior to the pass that installed the tubing. In the initial pass, root pruning was clearly evident as roots with diameters up to 2 inches appeared on the shanks. To reduce root pruning and improve the speed of tubing installation, the lines were moved out an additional foot to extend 5 feet on either side of the tree rows. After we installed the tubing, we flood irrigated the drip rows once to help settle the soil.

When flood irrigation was compared with buried drip irrigation in a Kings County pistachio orchard, there was a significantly lower incidence of Alternaria late blight with the buried drip system, *above*, because the orchard floor remained primarily dry.

Buried drip irrigation is installed using specialized heavy equipment, *above*. In this orchard, roots that were inadvertently pruned can be seen at the front of the shank.

Managing irrigation. Applied water amounts generally followed the water budget approach to irrigation scheduling. Reference crop water use (ETo) and published crop coefficients (Kc) were used to determine evapotranspiration. This information was adjusted to account for stored winter rainfall and for the limited surface evaporation with the newly installed



Red halos are characteristic of *Alternaria* fruit infections in pistachio.

Fruit from the buried drip orchard (left) was healthy, while the flood-irrigated fruit (right) suffered significant fungal damage. Aspergillus blight (bottom row), which occurs in drier orchard environments, was also monitored.

buried drip system. While the goal was to fully irrigate the trees, the timing in the surface irrigation treatment depended on soil infiltration and other horticultural practices. The cooperating grower made the irrigation decisions. At the peak of the season (July and August), flood irrigation occurred about every 10 days. Drip irrigation generally took place 3 to 4 times a week. To help reduce the possibility of surface wetting, the drip irrigation was pulsed (1 hour on, 1 hour off) when possible. The total applied water was about 27.5 inches and 29.5 inches per season in the flood and buried drip treatments, respectively. Winter rainfall averaged about 10 inches per season over the 2 years of this study.

Monitoring the disease. We collected fruit and leaves every 2 to 3 weeks from early May to mid-August to determine latent infections of *Alternaria* spp., using an overnight freezing incubation technique. Fruit and leaves were surface sterilized first in 70% ethyl alcohol for 10 seconds to 15 seconds and then with 10% chlorine bleach after adding 0.5% Tween-20 surfactant per liter for 4 minutes. We then allowed the fruit and leaves to dry and placed them in plastic containers over waxed wire screens. We held fruit and leaves at 3.2°F for 24 hours, then incubated them at 73°F after adding water to the containers. Developed colonies of *Alternaria* spp. were determined after 5 to 7 days of incubation. If we assume that this harsh surface sterilization procedure killed all the spores of *Alternaria* spp. on the surface, freezing should have triggered the growth of latent infections.

The first symptoms of the disease appeared in the orchard just before the middle of August in the first experimental year. We evaluated the incidence of infected leaves three times, on August 16 and August 26, and once at harvest (September 16). For each sampling, we collected 100 leaves per tree from nine trees in the middle rows of each replication, then evaluated them in the laboratory for the number of lesions per leaf (disease severity index). To determine the disease severity index, we classified infected leaves into three categories: (1) those with 1 to 5 lesions, (2) 6 to 10 lesions and (3) 11 or more lesions. Category (0) represented healthy leaves without *Alternaria* lesions (table 1).

Because fruit symptoms appear later than leaf symptoms, we evaluated the disease on the fruit only at harvest in both years. We collected 30 to 35 fruit clusters from each of nine trees per replicate and used 200 fruit subsamples per tree to evaluate ALB infection.

Since tree stress can affect fruit harvestability, the effectiveness of mechanical tree shaking in removing fruit (harvestability) was determined by individually shaking four trees per replicate and hand harvesting the fruit remaining in the tree. Gross fruit yields were determined by weighing all harvested fruit from the 10 interior rows per replicate. We used commercial analysis to assess nut quality, in terms of shell splitting, shell staining and insect damage.

Microclimate influence

In late June, single microloggers (electronic data storage devices) were placed in selected tree canopies located in the middle of adjacent repli-

TABLE 1. Mean incidence and severity of Alternaria late blight of pistachio leaves at harvest for two experimental years

Irrigation regimes	Infected leaves (%)			Leaf disease index†	Infected leaves total (%)
	1–5*	6–10	≥ 11		
Flood	27.9 a‡	10.7 a	15.9 a	0.97 a	54.5 a
Buried drip	8.0 b	1.5 b	0.8 b	0.14 b	10.3 b
LSD	2.9	2.8	3.8	0.15	5.5

* Number *Alternaria* lesions per leaf.

† Disease index was calculated with the formula: $DI = \frac{A \times 0 + B \times 1 + C \times 2 + D \times 3}{A + B + C + D}$

in which A, B, C and D = the number of leaves in each 0, 1, 2 and 3 disease severity categories, with 0, 1 to 5, 6 to 10, and 11 or more lesions per leaf, respectively.

‡ Values in each column not followed by the same letter are statistically different at the 5% confidence level using Duncan's new multiple range test.

By converting from flood to buried drip irrigation, the orchard microclimate can be significantly altered to improve the yield of marketable fruit, without fungicide sprays. Typical Alternaria late blight symptoms are apparent on pistachio leaves, *above.*

cates of both the flood and buried drip treatments, to record atmospheric conditions. Although the emitters had been placed deep in the soil (30 inches) and the drip system was pulsed, some surface wetting occurred (between 5% and 20% of the orchard floor). Nevertheless, orchard atmospheric conditions were dramatically different for the two irrigation regimes.

Higher maximum air temperatures (2°F to 3°F) were recorded with the buried drip in the season following installation (fig. 1A). Both relative humidity and the number of hours per day with relative humidity above 90% and above 95% were significantly lower with the buried drip (figs. 1B–1D). Similar climatic differences were recorded in the second experimental year. Dew duration on the leaves in the buried drip was generally much shorter than with the flood, differing by as much as 5 hours (fig. 2). These differences were greater just after the completion of a flood irrigation.

The reduced humidity clearly created a less favorable environment for disease infection and development. Although each replicate was 12 rows wide, there are spikes in the buried drip data that correspond to the flood irrigation dates (figs. 1 and 2). This bleed-over effect from the flood to the drip replicates reduced microclimatic differences between the irrigation treatments. One would expect even larger relative impacts on microclimate in orchards that are fully converted from flood to buried drip irrigation.

Fruit and leaf infection

The incidence of latent ALB fruit infection ranged from 43% to 90% from early May through mid-July in the first experimental year, but there were no significant differences between the irrigation regimes (fig. 3). This suggests that the green fruit was equally susceptible to the establishment of latent infections and that there was equal potential for the disease to develop afterward. However, by mid-August, 93% of fruit from flooded trees had latent infections compared with 72% of fruit from buried drip–irrigated trees. Similar results were obtained in the second monitored season. At harvest, ALB infection on fruit was 21% and 50% (first year) and 21% and 37% (second year) for the buried and flood treat-

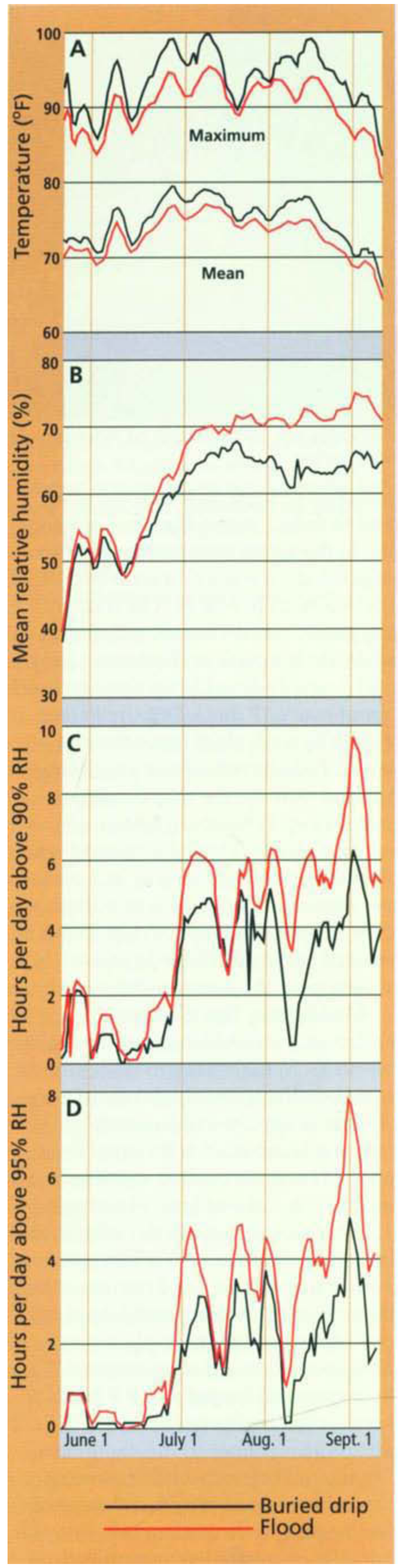


Fig. 1. (A) Temperature, (B) mean relative humidity (RH), (C) hours per day above 90% RH and (D) hours per day above 95% RH in adjacent flood and buried drip plots during the season following tubing installation.

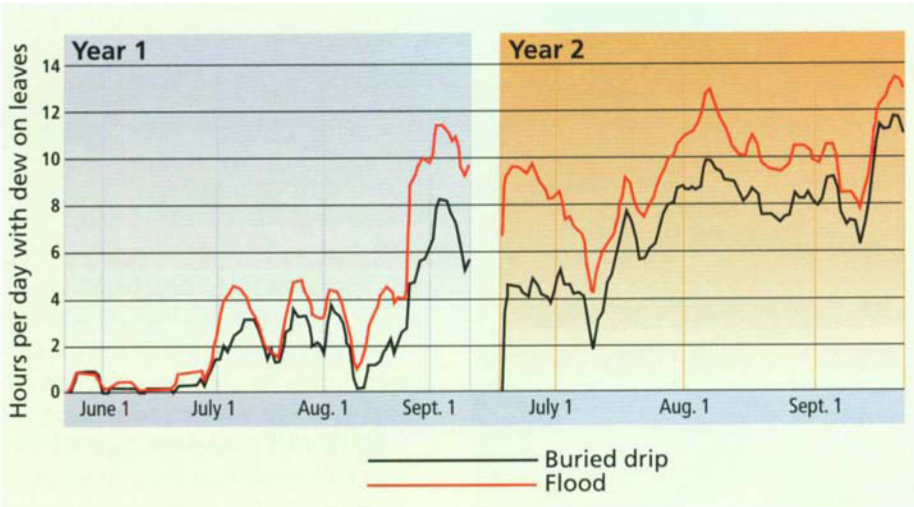


Fig. 2. Hours per day with dew on pistachio leaves in flood and buried drip irrigation regimes.

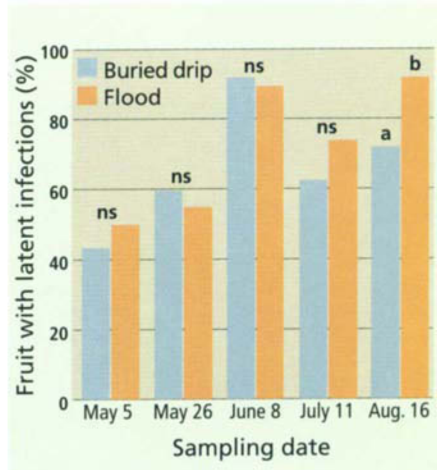


Fig. 3. Latent infection of pistachio fruit by *Alternaria* species determined by using overnight freezing incubation technique on samples collected periodically during first experimental year.

ments, respectively. These values were significantly different.

The overnight freezing technique also indicated that there were irrigation treatment differences in latent infections of fruit by *Aspergillus niger* (the pathogen causing Aspergillus blight of pistachio), which can also occur in drier orchard environments. Aspergillus blight can cause a bright yellow staining of the shell that is distinctly different from the brown-black staining caused by *Alternaria* species. In mid-August, 31% of the fruit from trees with the buried drip were infected by *A. niger* compared with only 16% collected from the flood irrigated trees — a statistically significant difference. However, at harvest there were no differences between the treatments, and less than 1% of the sampled fruit showed Aspergillus blight symptoms.

The first leaf symptoms of ALB appeared during mid-July in the first year and during the last week of July in the second year, and increased more rapidly with time in the flooded trees (fig. 4). At harvest, about 55% of the leaves in the flooded trees had ALB lesions compared with about 10% of those in trees irrigated by buried drip. The majority (77.7%) of the infected leaves in the buried drip replicates had only 1 to 5 lesions per leaf while 48.8% of the infected leaves in the flood replicates had six or more lesions per leaf (table 1). Therefore, altering orchard atmospheric conditions (temperature, humidity and leaf wetness duration) decreased the incidence and severity of the disease on leaves by 82%.

Fruit production

Mean gross yields for the 2 years of this study were somewhat lower (although not statistically so) with the buried drip irrigation (table 2). However, shell splitting was significantly greater with the buried drip; split nuts accounted for 59% and 70.5% of the harvested nuts on a dry weight basis for the flood and buried drip irrigation, respectively. We speculate that the disease-related leaf necrosis in the flooded trees reduced photosynthesis and, in turn, the sugars necessary for growth of the specialized cells that occur along the suture line of the shells and cause splitting. The improved shell splitting with the buried drip resulted in a significant increase in marketable product (table 2). We believe that the production differences between flood and buried drip irrigation would likely have been greater if the different systems could have been better isolated, as they would be if the entire orchard were converted to buried drip.

We anticipated that the primary benefit of reduced disease pressure would be less shell staining rather than improved shell splitting. Instead, shell staining was low and there was no significant difference between the treatments (table 2). We believe that the relatively low level of stain was due to the early harvest. Our grower-cooperator had learned by experience that he could avoid serious ALB degradation in this orchard by harvesting early. Early harvest (about 1 week to 2 weeks before normal harvest) of orchards with ALB can significantly reduce shell staining because *Alternaria* lesions on fruit do not have enough time to develop and decay the hulls. Our previous work showed that shell discoloration was related to fungal decay (Doster and Michailides 1999). Delaying harvests by 10 to 20 days significantly increased the number of nuts with excessive shell stain (greater than 10% of the outer surface of the shell discolored)(Doster and Michailides 1997). The downside of harvesting early is that shell splitting can be reduced. Insect damage varied little between irrigation treatments (table 2).

Sustainability of buried drip

While gross production was not affected by the different irrigation systems, we noted that the tree canopies

TABLE 2. Mean crop production parameters for the two experimental years

	Flood	Buried drip
Gross dry yield (lb./acre)	2,750 a*	2,571 a
Split in-shell (% dry wt.)	59.0 a	70.5 b
Total edible harvest split in-shell (lb./acre)	1,283 a	1,456 b
Stained light (% dry wt.)	14.3 a	14.5 a
Stained dark (% dry wt.)	5.83 a	4.88 a
Closed shell (% dry wt.)	40.9 a	29.4 b
Total insect damage (% dry wt.)	3.22 a	3.43 a
Removal of nuts by mechanical shaking† (% fresh wt.)	92.4 a	94.1 a

* Values in each column not followed by the same letter are statistically different at the 5% confidence level using Duncan's new multiple range test.

† Indicator of harvestability.

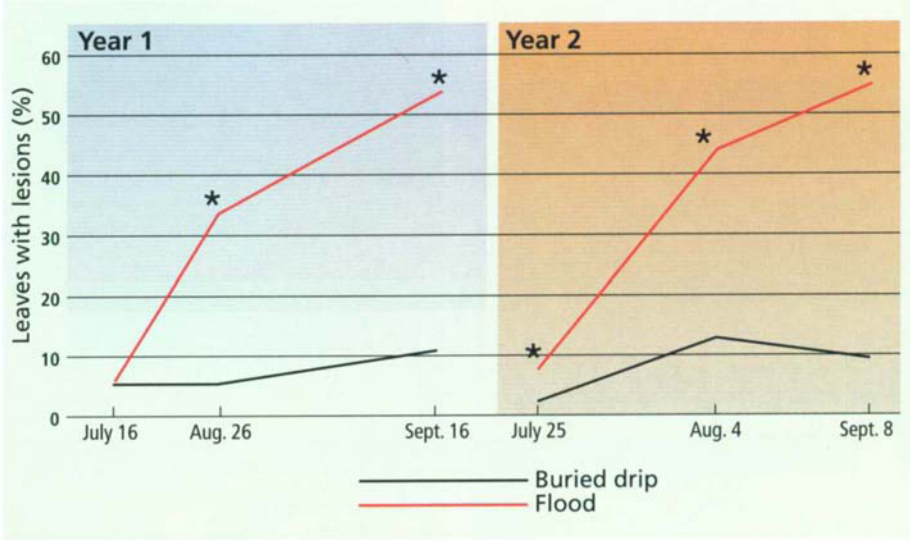


Fig. 4. Changes in percentage of pistachio leaves infected with Alternaria late blight over time. Asterisks indicate statistically significant difference between flood and buried drip irrigation regimes. (The last dates of recording the disease also indicate dates of commercial harvest.)

with buried drip were smaller than the flooded trees at the end of the season following installation of the tubing. We suspect that this was due to the severe root pruning that occurred during the installation; carbon assimilate that would normally have been available for canopy development was used by the increased root growth. We were concerned that production would be reduced in the following season(s) because fruit load can depend on the amount of fruit wood carryover from year to year. This fear was not borne out; there were no reductions in relative gross fruit yields in the buried drip trees for the two seasons following installation. Visual inspection showed that the tree canopy size differences evident in the season immediately following the installation of the buried drip lines had vanished by the second season.

Another concern with buried drip irrigation is emitter clogging. The grower-cooperator reports that after 6 years of operation, there has been no measurable decrease in the system operating flow rate. This suggests that root intrusion and clogging from particulate or organic material have been minimal. The grower-cooperator has visually inspected the emitters by digging pits and has verified that root intrusion is negligible. Growers must carefully monitor buried drip system performance, including flow rates, to ensure that they can identify the onset of any emitter clogging and take action.

We have shown that converting from flood to buried drip irrigation can alter orchard microclimate. In an orchard afflicted with a serious ALB problem, these changes can significantly improve the yield of marketable product. This approach to disease management is attractive in that it potentially saves water and reduces the need for fungicide sprays. Using buried drip irrigation to control fungal diseases may also be possible in other orchard crops where irrigation-related high humidity has been identified as the primary factor contributing to the disease (Teviotdale et al. 2001).

D.A. Goldhamer is Cooperative Extension Water Management Specialist, Department of Land, Air and Water Resources, T.J. Michailides is Professor, and D.P. Morgan is Staff Research Associate, Department of Plant Pathology, UC Davis, located at the Kearney Agricultural Center, Parlier. *The authors gratefully acknowledge the assistance of the cooperators, Nichols Pistachio, especially Chuck Nichols and John Starling; and Scott Britten of Bennett and Bennett Irrigation, who designed the buried drip system. They also express appreciation to Mario Salinas, Chuy Salinas, Miguel Marquez, Lorene Boeckler, Kevin Tsuda, Vincent Bajman, Adam Sullivan, Martin Ruepp, Adrian Ziliani and Nancy Flory for their help in field monitoring and sampling. The California Pistachio Commission provided partial funding for this work.*

References

Doster MA, Michailides TJ. 1997. The effect of delaying harvest on pistachio nut quality. California Pistachio Industry Annual Rep Crop Year 1996–97. Fresno, CA. p 82–4.

Doster MA, Michailides TJ. 1999. Relationship between shell discoloration of pistachio nuts and incidence of fungal decay and insect infestation. Plant Dis 83:259–64.

Michailides TJ, Morgan DP. 1993. Principles for the control of Alternaria late blight of pistachio caused by *Alternaria alternata* in California. Proc Ninth GREMPA Meeting-Pistachio, Bronte-Sciacca, Italy, May 20–21, 1993. p 56–63.

Michailides TJ, Morgan DP, Wang J. 1991. Control of Alternaria late blight of pistachio by manipulation of irrigation. Phytopathol 81:1163.

Teviotdale BL, Goldhamer DA, Viveros M. 2001. Effects of deficit irrigation on hull rot disease of almond trees caused by *Monilinia fructicola* and *Rhizopus stolonifer*. Plant Dis 85:399–403.

Focus groups show need for diabetes awareness education among African Americans

UC Health Promotion Workgroup

The UC Division of Agriculture and Natural Resources Health Promotion Workgroup assessed diabetes awareness among African Americans at risk for the disease. Workgroup members conducted focus group discussions with the target population in Los Angeles, San Bernardino, San Joaquin, San Mateo, Santa Clara and Stanislaus counties. Although obesity is considered a major risk factor for type 2 diabetes, most participants cited poor dietary patterns, rather than body weight, as the most important factor in the high rate of diabetes among African Americans. Food preferences, family pressure and lack of social support were most often mentioned as obstacles to healthful dietary changes. Many felt that not enough information about diabetes was reaching the black community and voiced the need for culturally sensitive education, delivered through community-based channels.

American Diabetes Association

The rate of type 2 diabetes is 1.6 times higher among blacks than whites; about 25% of African American women over age 55 suffer from the disease.

Over the past two decades, the prevalence of diabetes in the United States has increased by 33%, from 4.9% in 1990 to 6.5% in 1998 (Mokdad et al. 2000). Concurrently, California has experienced an increase of 67% in the prevalence of diabetes, from 4.1% to 6.9%. Experts believe these trends are due to the "obesity epidemic," as excess body weight is a major risk factor for type 2 diabetes.

Generally developing later in life, type 2 diabetes accounts for 90% to 95% of all cases and is characterized by insulin resistance and/or inability of the pancreas to deliver insulin in a regulated way to the cells. Type 1 diabetes, usually diagnosed during childhood or adolescence, involves an autoimmune process that destroys the insulin-producing cells in the pancreas. Those with type 1 diabetes must inject insulin, while people with type 2 usually control their diabetes through proper diet, exercise and/or oral medication. However, as the disease progresses or during pregnancy, even those with type 2 diabetes may need insulin.

The American Diabetes Association estimates that the direct and indirect costs related to all types of diabetes were more than $98 billion in 1997. Early detection and careful management of all types of diabetes through diet, physical activity and medication can lower the risk of complications and improve the quality of life.

The prevalence of type 2 diabetes is significantly higher in Native Americans, Latinos and African Americans than in non-Latino whites. Native Americans and Mexican Americans are two to five times more likely to have diabetes than non-Latino whites (Hosey et al. 1998, Harris et al. 1998). Although these two ethnic groups have a disproportionate rate of diabetes, the rate is 1.6 times higher in blacks than whites. In women, the rates are especially high: About one in four African American women over 55 has type 2 diabetes.

A number of factors may contribute to the increased risk of diabetes and diabetes-related complications in African Americans. In a study of 975 whites and 418 blacks, obesity accounted for 47% of the excess risk of diabetes in black women (Brancati et al. 2000). Genetic factors are also likely to play a role, but more research related to genetic and environmental influences is needed (Pi-Sunyer 1990,

For more information about diabetes, consult with your doctor or contact the American Diabetes Association, at 1-800-DIABETES (1-800-342-2383), or visit the Association's Web site at www.diabetes.org.

TABLE 1: Participant responses, diabetes focus groups (n = 60)	
Perceived cause:	**(n)**
Poor diet	18
Genetics/family trait	11
Stress	7
Lack of exercise	7
Lack of awareness	4
Lack of medical attention	3
Don't know	2
Other* (obesity, high cholesterol)	1
Perceived barriers to change:	**(n)**
Food preferences	17
Family pressure	10
Lack of social support	6
Forgetfulness	4
Lack of education	3
Age	2
Other (too much food in this society, overwhelmed, not enough money to go to a gym, lack of stores)	1
Perceived obstacles to health care:	**(n)**
Lack of cultural sensitivity/respect	6
Time/convenience/hours	3
Other (lack of insurance, fear, lack of free screenings)	1
Preferred educational channels:	**(n)**
Community-based outreach programs (community centers, gym, YMCA, health fairs, cooking classes)	10
Health providers	8
Schools	8
Churches	5
Peer counselors	4
Internet/Web	3
Brochures	3
Direct mail	3
Other (e-mail, videos, hotlines, restaurant billboards, buses, family, commercials, newspaper)	1

* All factors listed in "other" categories were mentioned one time in the discussion.

Schneider et al. 1997, Osei et al. 1993). Poor nutrition during pregnancy, resulting in newborns with low birth weights, may also contribute to increased risk of diabetes later in life. Low socioeconomic status may limit access to medical care and healthful foods, and increase sedentary behavior, but higher educational and income levels do not always have a protective effect in African Americans (Gaillard et al. 1997). Racial discrimination, which has been linked to hypertension in African Americans, may undermine health promotion efforts and could also be a factor (Krieger and Sidney 1996).

A recent study involving a multicenter, randomized, controlled trial reported that intensive lifestyle changes can reduce the incidence of type 2 diabetes over a 3-year period by as much as 58% in populations at risk (Diabetes Prevention Program Research Group 2002). These lifestyle changes included 30 minutes of moderate physical activity on most days of the week, a weight loss of 7% and a low-fat diet.

Lifestyle modifications, such as a healthier diet, weight management and moderate physical activity, can delay the onset of diabetes. Using focus groups, UC researchers examined the perceived causes of diabetes and barriers to change among African Americans who had not been diagnosed with the disease.


American Diabetes Association

Sustaining intensive lifestyle changes over the long term may be difficult without agricultural and environmental developments that increase public access to a low-fat diet and encourage physical activity. Nevertheless, if lifestyle changes could delay the onset of diabetes by only a few years, the personal benefits and savings in health care costs would be substantial. For example, during the first year after diagnosis, health care costs per person are 100% higher for people with diabetes compared with those who don't have diabetes. Eight years after diagnosis, costs are 133% higher (Brown et al. 1999). However, to reduce diabetes rates in minority populations at risk, more research is needed to develop culturally sensitive approaches to communication and education (Diabetes Research Working Group 1999).

Assessing needs and perceptions

A workgroup of UC faculty, Cooperative Extension specialists and county advisors conducted a series of focus groups with African American adults to examine beliefs and perceptions about diabetes. This work was carried out in preparation for a larger campaign to increase awareness and reduce risk factors in the same population. The focus groups took place in Los Angeles, San Bernardino, San Joaquin, San Mateo, Santa Clara and Stanislaus counties. Workgroup members developed the research protocol, formulated focus group questions and interpreted the results. Through phone calls, church bulletins and personal contacts with agency staff and pastors, advisors recruited a convenience sample of participants from churches, clinics, housing projects and other community organizations. To be included in the study, participants had to be African American, between 20 and 50 years old and have not received a diagnosis of diabetes.

Seven focus groups (two in Los Angeles, one in each of the five other counties) were conducted among African American adults in church or clinic settings. The same person, an

Focus group responses:
Causes of diabetes

"I don't think it is hereditary. It's eating habits handed down generation to generation."
— *Santa Clara County*

"We don't get the prevention and education ahead of time, so it passes down through generations. We have family that came here from Louisiana. They brought that part with them — the history, the eating and the cooking. It starts when we are infants: 'Give that baby some chili beans and corn bread. Feed that baby.'" — *San Joaquin County*

"A lot of different problems, especially prevalent among African Americans, could be attributed to food and stress. You eat when you are stressed or tired."
— *Santa Clara County*

Family pressure and social support in the workplace were often cited as barriers to changing eating habits or losing weight.

African American woman, moderated each group to maintain consistency and establish a comfortable and friendly environment that encouraged the open sharing of ideas and opinions. In all but one county, an advisor acted as a co-moderator. The moderator followed a standardized focus group protocol, using open-ended questions, probes and cues, as recommended by R.A. Krueger (1994). The participants were offered refreshments and given a $25 incentive to attend the sessions.

All sessions, except those in Los Angeles, were tape-recorded by the co-moderators and later transcribed by a graduate student with the UC Davis nutrition department. In Los Angeles, only the notes were available for analysis. Each of the co-moderators was asked to cross-check the transcripts from his or her county and provide overall impressions of the emerging themes at a workgroup meeting. A nutrition specialist coded and categorized segments of the transcripts using the QSR Nud*ist Version 4 software (Sage Publications, Thousand Oaks, CA). The moderator and another nutrition specialist independently hand-coded and categorized segments to determine the major and minor themes.

The focus groups began with general introductory questions about what people already know about diabetes (what they may have heard from others; whom do they know with the disease). Transition questions focused on factors contributing to the high rate of diabetes among African Americans and the importance of screening. The key questions concerned what advice they would give others who have symptoms, any obstacles they face in changing health practices and awareness of community resources related to diabetes. Final questions concerned how people prefer to receive information and what specific diabetes-related topics should be addressed (table 1).

Focus on dietary role

Sixty African American adults participated in the study: 30% (n = 18) in Los Angeles County, 18% (n = 11) in San Bernardino, 12% (n = 7) in San Joaquin, 15% (n = 9) in San Mateo, 7% (n = 4) in Santa Clara and 18% (n = 11) in Stanislaus. The average age was 32 years, ranging from 20 to 50. None of the participants had been diagnosed with diabetes, although at least one had had gestational diabetes. Forty percent (n = 24) had at least one relative or family member with diabetes. Most of the participants were native Californians (62%, n = 37). Eighty-two percent (n = 49) of the participants were female and 18% (n = 11) male. According to the advisors who recruited for the study, the groups included all low- and middle-income persons.

Perceived causes of diabetes. Although many people were uncertain about the cause of diabetes, dietary factors were mentioned most often as contributing to a high rate among African Americans. Most pointed to general eating habits — too much sugar, fat and "soul food." Several talked about their love for the spicy or well-seasoned foods prepared by other family members. Some talked about the link between current eating patterns and traditional foods passed down through generations since slavery. About equal numbers mentioned lack of exercise and stress as contributing factors. One person commented that African Americans were not targeted for messages that encourage physical activity. Although almost half (n = 24) had at least one immediate family member with diabetes, some participants were uncertain about the link between heredity (genetics) and diabetes. Being overweight was mentioned only once as a contributing factor. Further research is needed to clarify how the target group links poor dietary patterns to diabetes.

Barriers to change. Frequently, participants mentioned the difficulty of changing eating habits such as by limiting the intake of fat and sugar and avoiding cultural foods. Several mentioned family pressure, particularly at celebrations, and a lack of social support in the workplace. Other obstacles mentioned were age, lack of stores offering a variety of healthy foods in minority neighborhoods and "too much food in this society." One mentioned not having enough money to go to a gym.

Obstacles to health care. Lack of cultural sensitivity and respect among health providers was mentioned most

Focus group responses: Barriers to change

"My fiancé is from the South and loves fried chicken. I am trying to lose weight, and it is tough to feed him. It doesn't matter how much seasoning or whatever I put on it when my heart wants fried chicken or fish."
— *Stanislaus County*

"In family gatherings, people are not supposed to diet but are supposed to eat their foods. There is that kind of family pressure."
— *San Mateo County*

"People bring in lots of sweets to work, and even if you don't want any, you might one day give in and eat one donut, which increases to two and so on. Also, at home, when the rest of the family is eating fried chicken and sweets it makes dieting difficult."
— *San Bernardino County*

Focus group responses: Obstacles to health care

"Even at the doctor's, you see nothing [about diabetes]. You see AIDS, breast cancer, lung cancer. How are we going to fight back, because we don't have anything to fight back with? We don't know anything." — *San Joaquin County*

"Race is an issue. Minorities are not treated on even par. We need to be educated to become more responsible and take responsibility for our health."
— *Los Angeles County*

"Don't come out here with the diabetes information on wheels. It's a different person each week. If they put that on wheels, that is not enough consistency. That is lack of respect for a person."
— *San Joaquin County*

Focus group responses: Receiving education

"Church is a good place. You are already there. Have a nurse sit at the table and give you information."
— *Santa Clara County*

"I want it to be reinforced, so I think it should come from the doctor or someone I can trust, like my OB [obstetrician]."
— *Santa Clara County*

"Community fairs and things like that. I will go and listen to what they say. I have this thing with paper lately — I don't like to take the stuff anymore, but I will listen to somebody." — *Stanislaus County*

"You can send all the fliers you want into the black community, but if it's not presented right, you can hang it up, they will not listen."
— *San Joaquin County*

often as a barrier to early screening and preventive health care. Awareness of county-based resources related to diabetes varied widely. In San Joaquin County, participants were particularly vocal about obstacles to care, and no one was able to cite any relevant community resources. Although most viewed early screening as very important and would encourage anyone having symptoms to see a doctor, participants also expressed distrust and dissatisfaction with the health care system. Many felt they were not receiving information about diabetes or even being screened for the condition. Other factors mentioned were lack of free screenings, fear, time, inconvenience and lack of awareness.

Preferred channels for education. Four channels mentioned most often were community-based organizations (including health fairs, gyms, cooking classes), health providers, schools and churches. Participants were divided on the usefulness of disseminating diabetes materials via schools to parents, but agreed that children should be receiving this information early in their education. Opinions were also divided about the benefits of direct mail. Other channels mentioned were the Web or e-mail, posters on buses, billboards, public service announcements, family members, peer counselors, hotlines, brochures and restaurants. The diversity of channels mentioned probably reflects the differences in socioeconomic status and age among the groups.

Participants emphasized the need for information to be presented well. Effective approaches included using trained African Americans from the communities to take the message to the people. One participant suggested using the term "if you have sugar" to help people link their symptoms to diabetes and the need for screening. Being able to talk to people who have diabetes was also viewed as important.

Desired information. Many people knew something about the symptoms and dire consequences of diabetes, but their comments also reflected a lot of misinformation, such as that eating too much sugar causes diabetes. Most people wanted more information on causes, prevention and symptoms. They also wanted to know who's at risk, the types of diabetes, how often they should be screened, if diabetes is curable and the progression of the disease. Other information sought included: how to deal with diabetic coma, effect of diabetes on bones, how to eat right, lifestyle tips, alternative foods, new research on diabetes, how to control diabetes, how to lose weight and community resources.

Interventions and next steps

Since few in this study specifically linked being overweight with diabetes, interventions to prevent diabetes in African Americans might be more culturally acceptable — and possibly more effective — if issues related to dietary practices, the flavor and appeal of foods, social support and physical activity were addressed first. Many participants in our study also felt they had not received enough information about diabetes from the usual channels, given the relatively high risk of diabetes in the African American community. Participants also emphasized the need for culturally sensitive, community-based approaches to health promotion.

Findings from focus groups always should be viewed as qualitative and not necessarily representative of the population at large. The participants in our focus group discussions may have been more interested in the topic than others who did not volunteer for the study. Issues raised in certain groups may also have depended on the level of comfort participants felt in that setting.

Nonetheless, studies conducted among African Americans in other states have described similar themes. Particularly among older adults, the history of slavery is perceived to influence food choices (Airhihenbuwa et al. 1996). A major issue in diabetes management is the importance of food and eating in black culture (Anderson et al. 1996, El-Kebbi et al. 1996). The need for strong family support when following a diet and dissatisfaction with health providers has also been mentioned in other focus groups with black adults (Maillet et al. 1996). Other studies suggest that health providers may not be providing enough diabetes-related information to their patients (Jefferson et al. 2000).

Information gathered in the focus groups is being incorporated into a pilot outreach program — a series of cooking workshops targeting African Americans. About two-dozen community members attended a recipe-testing workshop sponsored by UC Cooperative Extension in San Joaquin County, where they prepared, sampled and gave researchers feedback on healthier versions of traditional African American recipes.

The faith community or church is increasingly recognized as an important channel for health promotion messages targeting African Americans (Oexmann et al. 2000, McNabb et al. 1997). Black women with diabetes are almost four times as likely as white women to receive diabetes information through their churches (Schoenberg 1998). A community-based program, delivered by trained lay volunteers through the churches, can be as effective as clinic-based programs in achieving weight loss in African Americans (McNabb et al. 1997).

Based on these findings, the Health Promotion workgroup is now planning a multichannel campaign, working closely with the African American community. The components include: cooking classes using modified African American recipes; opportunities in small group settings to talk with health providers about diabetes-related services; and visual messages disseminated through the African American community via clinics, schools and churches. The goals of this campaign and related activities are to raise the level of diabetes awareness and promote earlier screening and treatment for the disease. A secondary goal will be to motivate people to adopt healthier lifestyles that reduce the risk of developing type 2 diabetes.

UC Health Promotion Workgroup members who authored in this study are: Lucia L. Kaiser, Marilyn S. Townsend, Francene M. Steinberg and Amy B. Joy, Department of Nutrition, UC Davis; Estella A. West, UC Cooperative Extension (UCCE) Santa Clara County; Gloria R. Brown, UCCE San Mateo County; Nancy I. Feldman, UCCE Stanislaus County; Connie L. Garrett, UCCE San Bernardino County; Anna Martin and Anna Olivares, UCCE San Joaquin County; Edwina U. Williams, UCCE Los Angeles County; Christine M. Bruhn, Department of Food Science and Technology, UC Davis; and Marciel A. Klenk, UCCE Napa County.

References

Airhihenbuwa CO, Kumanika S, Agurs D, et al. 1996. Cultural aspects of African American eating patterns. Ethnicity Health 1(3):245–60.

Anderson RM, Barr PA, Edwards GJ, et al. 1996. Using focus groups to identify psychosocial issues of urban black individuals with diabetes. Diabetes Educator 22(1):28–33.

Brancati FL, Kao LWH, Folsom AR, et al. 2000. Incident type 2 diabetes mellitus in African American and white adults. JAMA 283(17):2253–9.

Brown JB, Nichols GA, Glauber HS, Bakst AW. 1999. Type 2 diabetes: Incremental medical care costs during the first 8 years after diagnosis. Diabetes Care 22(7):116–24.

Diabetes Prevention Program Research Group. 2002. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. New England J Med 346(6):393–403.

Diabetes Research Working Group. 1999. Summary of the report and recommendations of the Congressionally established Diabetes Research Working Group. www.diabetes.org/ada/drwg/drwgsummary.html.

El-Kebbi M, Bacha GA, Ziemer DC, et al. 1996. Diabetes in urban African Americans V: Use of discussion groups to identify barriers to dietary therapy among low-income individuals with non-insulin-dependent diabetes mellitus. Diabetes Educator 22(5):488–92.

Gaillard TR, Schuster DP, Bossetti BM, et al. 1997. Do sociodemographics and economic status predict risks for type II diabetes in African Americans? Diabetes Educator 23(3):294–300.

Harris MI, Flegal KM, Cowe CC, et al. 1998. Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults. Diabetes Care 21(4):518–24.

Hosey G, Gordon S, Levine A. 1998. Type 2 diabetes in people of color. Nurse Practitioner Forum 9(2):108–14.

Jefferson VW, Melkus GD, Spollett GR. 2000. Health-promotion practices of young black women at risk for diabetes. Diabetes Educator 26(2):295–302.

Krieger N, Sidney S. 1996. Racial discrimination and blood pressure: The CARDIA study of young black and white adults. Am J Public Health 86(10):1370–8.

Krueger RA. 1994. *Focus Groups.* Thousand Oaks, CA: Sage Publ. 255 p.

Maillet NA, Melkus GD, Spollett GR. 1996. Using focus groups to characterize the health beliefs and practices of black women with non-insulin-dependent diabetes. Diabetes Educator 22(1):39–46.

McNabb W, Quinn M, Tobian J. 1997. The Pathways church-based weight loss program for urban African American women at risk for diabetes. Diabetes Care 20(10):1518–23.

Mokdad AH, Ford ES, Bowman BA, et al. 2000. Diabetes trends in the U.S.: 1990–1998. Diabetes Care 23(9):1278–83.

Oexmann MJ, Thomas JC, Taylor KB, et al. 2000. Short-term impact of a church-based approach to lifestyle change on cardiovascular risk in African Americans. Ethnicity Dis 10:17–23.

Osei K, Cottrel DA, Ezenwaka EC, et al. 1993. Serum insulin and glucose concentrations in people at risk for type II diabetes. A comparative study of African Americans and Nigerians. Diabetes Care 16(10):1367–75.

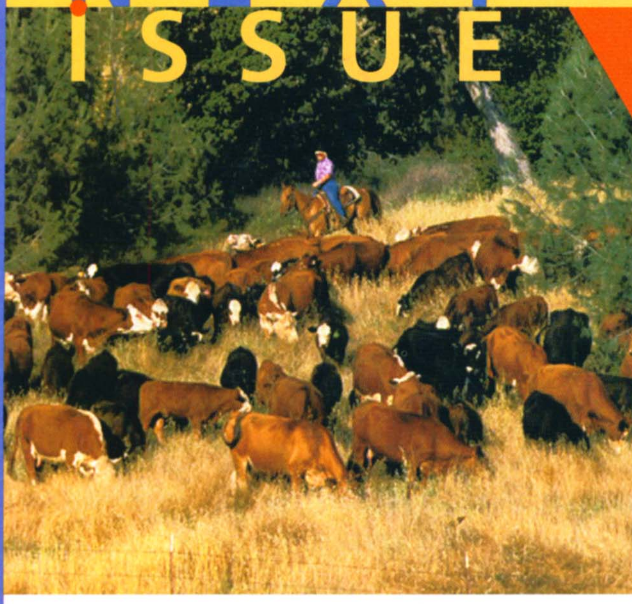
Pi-Sunyer FX. 1990. Obesity and diabetes in blacks. Diabetes Care 13(11, suppl 4):1144–9.

Schneider D, Greenberg M, Lu L. 1997. Early life experiences linked to diabetes mellitus: A study of African American migration. J Nat Med Assoc 89:29–34.

Schoenberg NE, Amey CH, Coward RT. 1998. Diabetes knowledge and sources of information among African American and white older women. Diabetes Educator 24(3):319–24.

NEXT ISSUE

Jack Kelly Clark



Raising cattle. . .

Garnering more than $1.3 billion annually, beef cattle and calves are one of California's most important agricultural products, ranking fourth only behind grapes, dairy and nursery products. However, the California cattle industry is at a crossroads. Industrywide consolidation is having a significant impact; the number of major in-state slaughter facilities dropped from 52 in 1972 to just three in 1997, and much of the cattle produced here is shipped out of state. In the next issue, UC agricultural economists survey California ranchers in 40 counties and explore the role of trends such as feed supplies, consolidation, marketing, contracts and buyers on the state's rapidly changing cattle and calves market.

. . . and making hay

Also coming up, UC scientists describe important research on the water quality impacts of various insecticide applications in alfalfa. Alfalfa is grown on about 1 million acres in California, with an annual value of between $700 million and $1 billion. Tail water was collected from dozens of farms in the northern Sacramento Valley for 3 years, *above*. Based on the findings, the use of insecticides damaging to aquatic life has been reduced significantly in alfalfa grown in two of the region's counties.

Visit *California Agriculture* on the Web:

http://danr.ucop.edu/calag/

ANR University of California

calag@ucop.edu
Phone: (510) 987-0044
Fax: (510) 465-2659