The Agricultural Experiment Station

at Colorado State University developed this

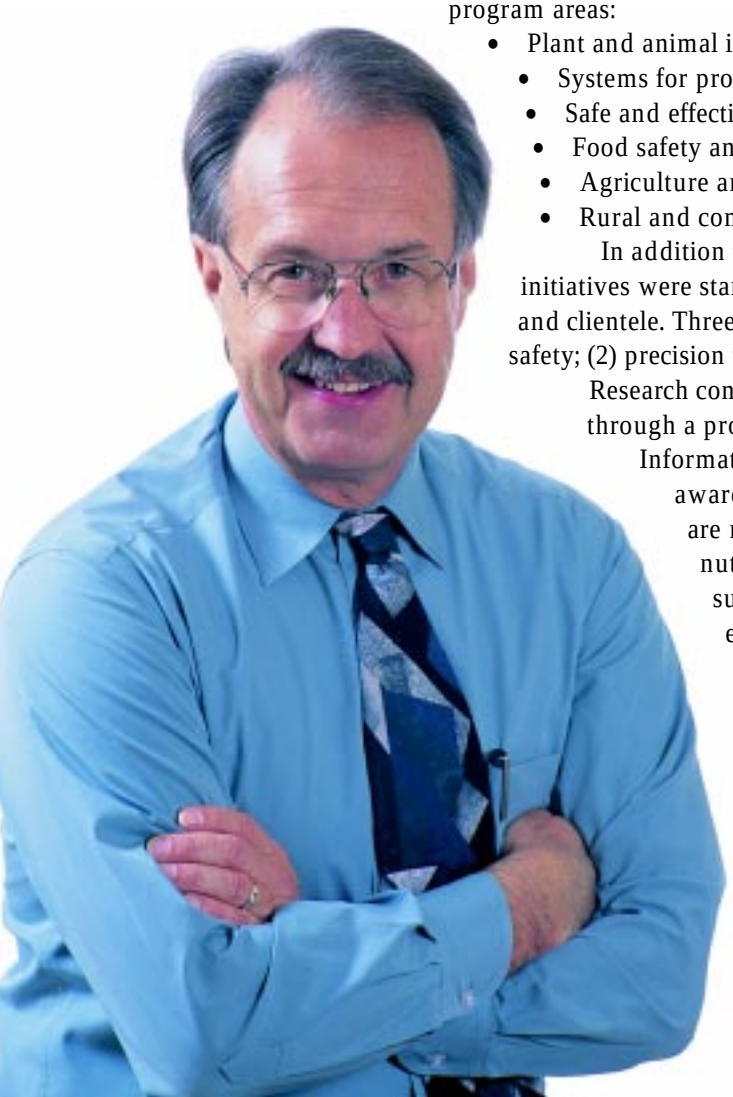
annual report to summarize the results obtained by a

selection of our ongoing research projects. As an integral part of

Colorado State University, the Agricultural Experiment Station is committed to

implementing the University's land-grant mission by conducting research on the agricultural and environmental needs of the people of Colorado, the region, and the nation. Our mission is to support research leading to an agriculture that is economically viable, environmentally sustainable, and socially acceptable. Our agricultural research efforts extend across the entire campus involving faculty and staff from 22 academic departments in 7 colleges. To address the complex problems facing agriculture, it is essential that academic departments work in concert with each other to solve problems through interdisciplinary effort.

The diverse program supported by the Agricultural Experiment Station can be characterized in six broad program areas:



- Plant and animal improvement and new agricultural product development
- Systems for producing, processing, and marketing agricultural products
- Safe and effective management of agricultural pests
- Food safety and nutrition
- Agriculture and environmental quality
- Rural and community development

In addition to our ongoing base program in the above areas, four new research initiatives were started during the past year in response to needs identified by faculty and clientele. Three-year projects have been initiated in the following areas: (1) food safety; (2) precision farming; (3) salinity in the Arkansas Valley; and (4) animal waste.

Research conducted in the Agricultural Experiment Station also is enhanced through a program co-funded by the Vice President for Research and Information Technology. This past year, five two-year projects were awarded a total of $400,000 through the joint program. These projects are multi-disciplinary efforts in animal reproduction, animal disease, nutrition, precision farming, and wheat biotechnology. Joint efforts such as this enable research on mission-oriented topics, as well as enhance the capability of our faculty to secure extramural funding from state and federal agencies.

I hope you enjoy this report. Please contact me if you have any questions concerning our research programs at Colorado State University.

Lee E. Sommers, Director
Colorado Agricultural Experiment Station
at Colorado State University

It takes a whole bag of tricks to raise a good hay crop in Colorado's mountain meadows.

The growing season is short. Soils are shallow, often boggy. Noxious weeds, erosion, economics, and management practices add to the challenge.

That's where Joe Brummer, research scientist at the Mountain Meadow Research Center in Gunnison, comes in. He tinkers with old tricks to see if he can improve them. And he has some new tricks up his sleeve, too.

One popular old trick turned out to be a dud when Brummer took a close look at it. Many mountain hay meadows have developed a thick layer of peat, a sort of built-in compost pile. The peat is rich in nitrogen, but not in a form plants can use. In theory, aerating this peat layer should stimulate soil microbes to break down the nitrogen, like turning a compost pile. In practice, Brummer's research showed that this actually reduced hay production instead of stimulating it.

Meadow foxtail, introduced some time ago, is well adapted to our mountain meadows. A prolific seed producer, it has spread throughout Colorado's mountain valleys. With nitrogen fertilization, producers can get good yields. But as a livestock feed crop, meadow foxtail's nutritional value leaves a lot to be desired. Unfortunately, additional fertilizer doesn't solve this problem.

One way to improve feed quality is to introduce legumes into the meadow. Not only do legumes improve the hay's feed value, their nitrogen-fixing ability reduces or eliminates the need for nitrogen fertilizer. This both saves money and reduces the risk of nitrogen runoff or groundwater contamination.

"The hard part about interseeding is getting the plants established," says Brummer. "Seeding alone doesn't work. The existing grasses shade the new plants and they can't get a good start." Traditional practice has been to spray Roundup to completely suppress the grass. The new species is then seeded and can establish itself for a year before the grasses recover from the Roundup. But the rancher forfeits an entire year's hay crop and has to buy hay to replace it. Another option is to completely renovate the meadow – plow the whole thing up and reseed it from scratch. This is an expensive undertaking, and the rancher still loses one or more hay crops.

Brummer tried several tricks to improve the success rate of interseeding. Instead of spraying a whole meadow, he sprayed bands within it, then seeded those bands. The legumes could establish themselves within those bands, and the rancher could harvest hay as usual on the uncontrolled areas.

Like most things in life, there is a trade-off. Strip interseeding gave only about half as good a stand of new legumes as spraying the whole meadow. On the plus side, though, ranchers harvested at least a partial hay crop from the uncontrolled strips.

TRICKS O

Another Brummer trick is birdsfoot trefoil. This legume, widely grown in the northeastern United States, adapts well to Colorado's wet mountain meadows but hasn't been widely grown here. Test plots showed improved protein and digestibility over both alfalfa and clover, the two legumes most commonly used in Colorado.

Brummer has found his tricks in some unusual places. While searching for information on applicators to apply herbicides in bands, he found a Web page from a farmer in Tasmania, an island off Australia. The farmer had developed pads for wiping herbicides on plants instead of spraying. The technique sounded like just what Brummer was looking for. He tried them last year with good results. More tests are in the works.

"Every ranch is unique," says Brummer. "Unique in the physical sense, of course, but also in the rancher's financial and management goals. So no one answer will work for everybody." That's why he needs a whole bag full of tricks.

Increasing

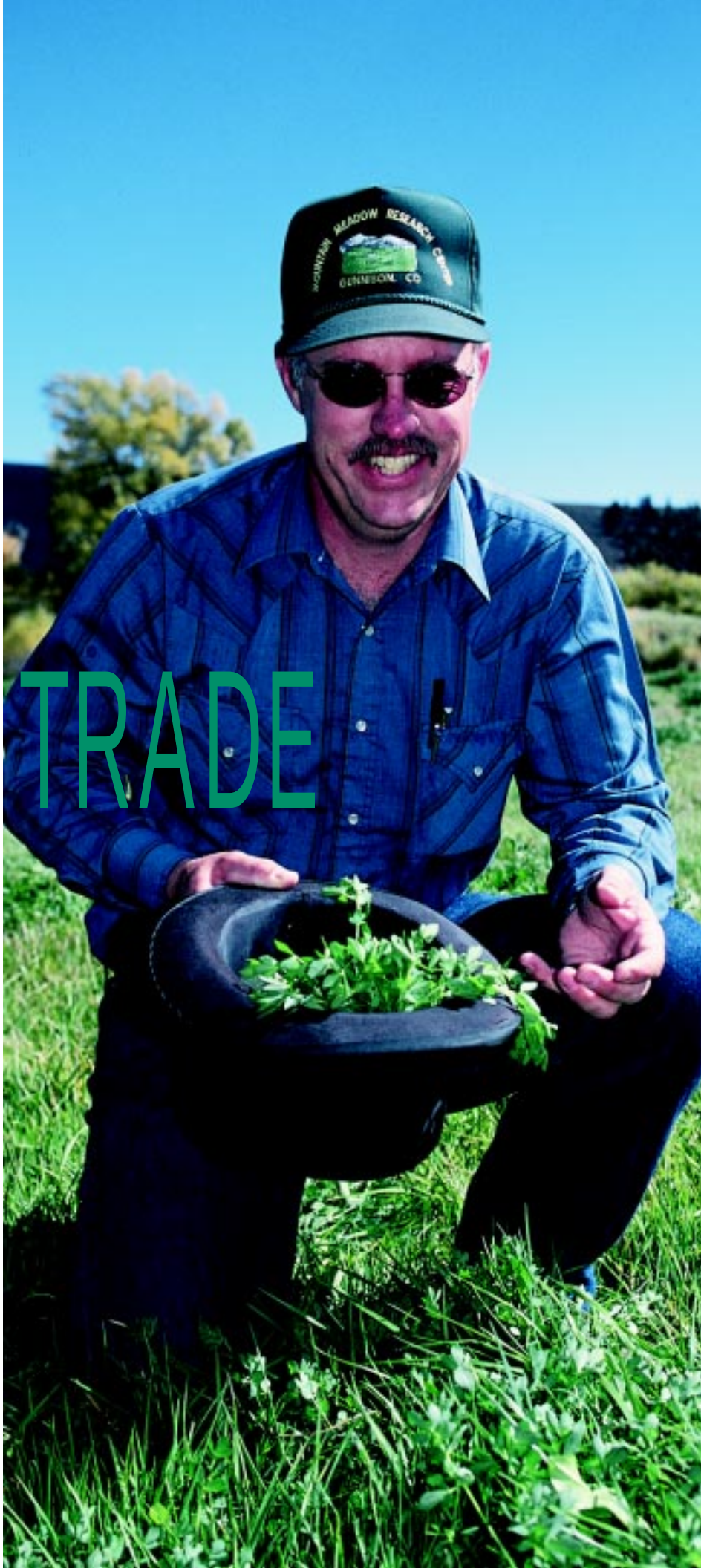
hay yields

in high

OF THE HAY TRADE

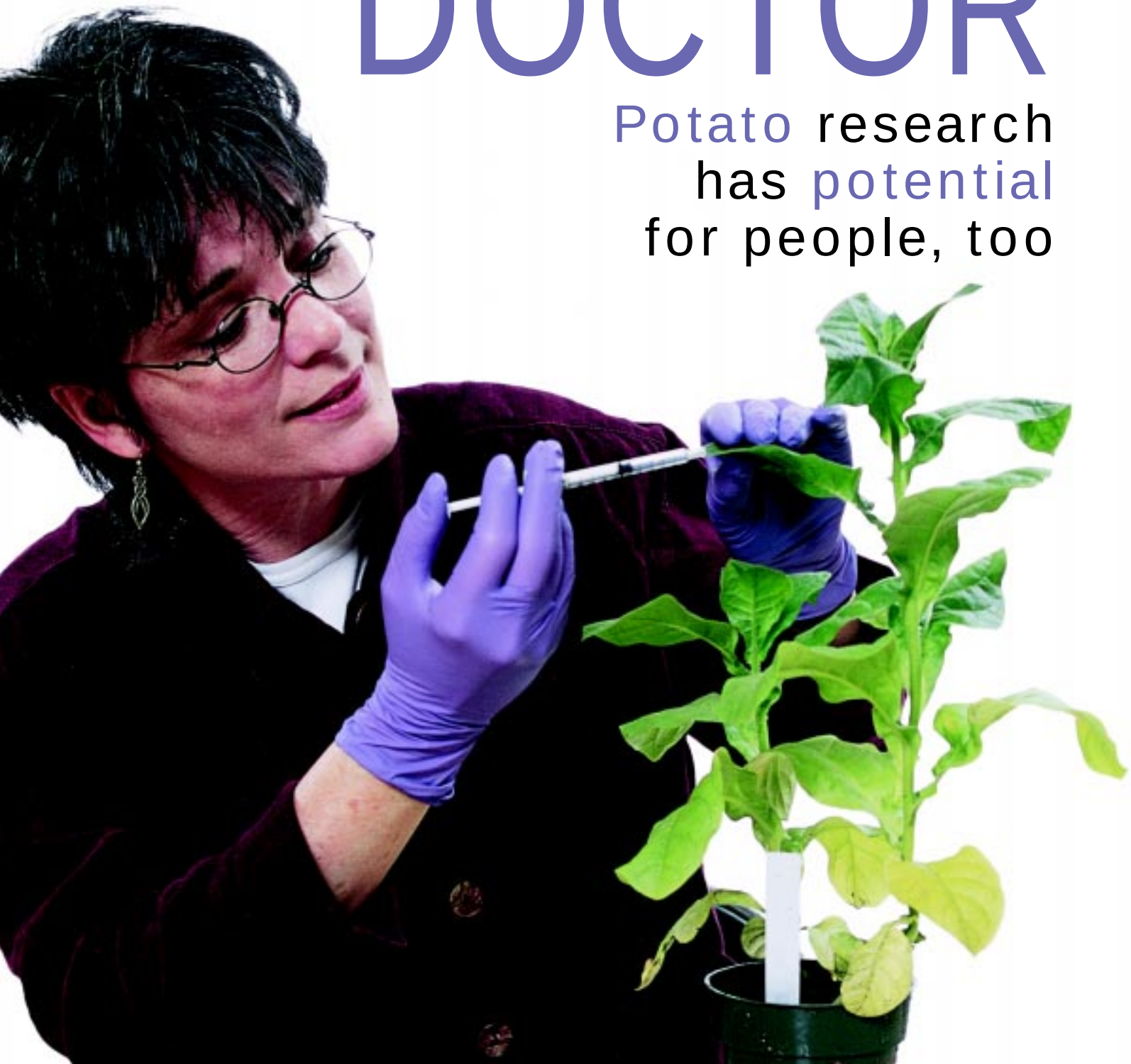
mountain

meadows



THE PLANT DOCTOR

Potato research has potential for people, too



Plant medicine

isn't so very different

from people medicine,

when you get right down to it.

Sometimes even closely related bacteria are involved.

Carol Ishimaru, associate professor in bioagricultural sciences and pest management, tackles potato diseases using many of the methods and tools that other researchers use to tackle human diseases.

Ishimaru's target is bacterial ring rot of potatoes. "The disease is incurable. If just one diseased plant is found in a field, the whole field can be rejected as seed stock. This can cost a grower as much as $80,000, just for that one field."

Because ring rot spreads so quickly and easily, potatoes must be inspected and certified before they can be used as seed stock. Even table stock potatoes must be certified before they can be exported. U.S. certification standards are based on the presence of diseased plants. Canadian and European standards test for the pathogen itself. This difference in standards limits U.S. access to potential export markets.

Plant resistance allows producers to meet U.S. certification standards, but it does nothing to either help potato exporters or slow the spread of the disease. Resistant plants can harbor the bacteria without showing any symptoms. This can mask the presence of the disease and actually contribute to its spread.

"The only true defense against ring rot is prevention," says Ishimaru. Prevention is best accomplished by identifying the bacterium before it does its damage. But not all strains of *Clavibacter michiganensis* subs. *sepedonicus* cause disease; some are benign. So it is important to identify not just the bacterium, but the strain as well.

One way to separate disease-causing strains from their benign counterparts is to look for a contained suicide response. Researchers inject a nonhost plant, such as tobacco, with *C. michiganensis* subs. *sepedonicus* bacteria. If those bacteria represent a virulent strain, the tobacco plant kills off the infected parts of its leaves to contain the infection. If the strain is not virulent, there is no reaction.

C. michiganensis subs. *sepedonicus* is gram-positive. That is, one of the methods for identifying this particular bacterium is that it retains a blue color when treated with a special dye called Gram's stain. When Ishimaru began her investigation, very little study had focused on gram-positive bacteria. Ishimaru's research was further complicated by the fact that gram-positive bacteria are very difficult to grow in laboratory conditions.

Ishimaru teamed up with Penny Bauer, professor of bioagricultural sciences and pest management, and researchers in Finland and Canada. In 1997, they showed that gram-positive bacteria can elicit the same contained suicide response in tobacco as their gram-negative counterparts. This breakthrough paves the way for developing genetically engineered resistance to diseases caused by gram-positive bacteria, as has been done for diseases caused by gram-negative bacteria.

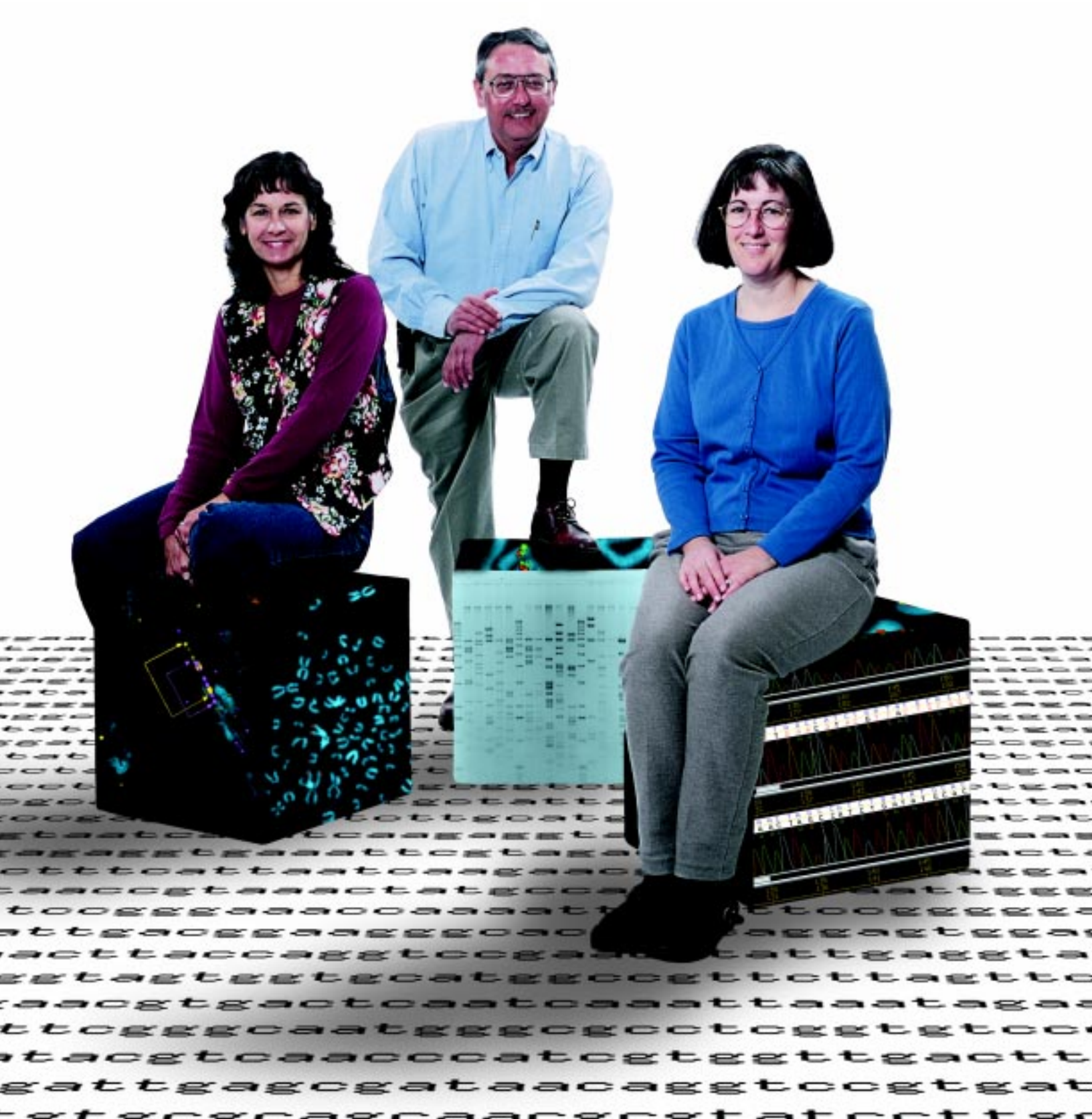
But plant resistance to ring rot isn't what Ishimaru is after. She is now focusing on identifying the disease-causing regions in the DNA of these bacteria. She works closely with Dennis Knudson and Susan Brown and their genome mapping team to isolate and mark these regions.

"Our goal is to come up with a specific, reliable, and sensitive test to identify virulent strains of the bacteria," says Ishimaru.

With such a test, potato growers could tell whether a field harbored a virulent strain of *C. michiganensis* subs. *sepedonicus*. If it did, they can use sanitation, crop rotation, and other cultural practices to eliminate the disease. Such a test would also open up export markets for U.S. producers.

While Ishimaru focuses on a single potato disease, her work has implications far beyond that. Gram-positive bacteria are responsible for such human scourges as tuberculosis, diphtheria, and staph. Her work with the lowly potato could open new doors for preventing these and other diseases in people, too.

THE CODEBREAKERS



From mosquitoes to potatoes, genomics unlocks DNA secrets

"The toll of insect-borne diseases is staggering," says Dennis Knudson, professor of bioagricultural sciences and pest management.

"Worldwide, hundreds of millions of people are infected with malaria at this very moment. Three billion people – more than half the world population – are at risk for contracting the disease. Millions died from it last year, and that's just one disease of many carried by insects, ticks, and their brethren."

Knudson has been a faculty member at Colorado State University for the past 12 years. His research interests have ranged from virology to genomics and from insects to plants. His insect pest of interest is the yellow fever mosquito, *Aedes aegypti*. Knudson and his colleague, Susan Brown, trace their interests in mosquitoes and infectious disease to their work at the Yale Arbovirus Research Unit, Yale University School of Medicine. In 1998, Janice Stephens, a Colorado State graduate, joined the team with her expertise in plants, histology, and cytogenetics. Undergraduates Mario Carmosino and Philip Stephens round out the research team.

The team is studying the molecular and genetic pathways that enable mosquitoes to transmit parasitic diseases. They hope to determine why some mosquitoes transmit the disease and others do not. Such knowledge will open the door to new ways to control these infectious diseases.

By now most people have heard of DNA fingerprinting, widely used in criminal trials. Less well-known, but just as important, are other tools used in genomics: fluorescent *in situ* hybridization (or FISH) physical mapping, DNA sequencing, polymerase chain reaction (PCR), and bioinformatics. "The chance to learn all these new procedures as well as using my own expertise is what attracted me to be part of the team," says Stephens.

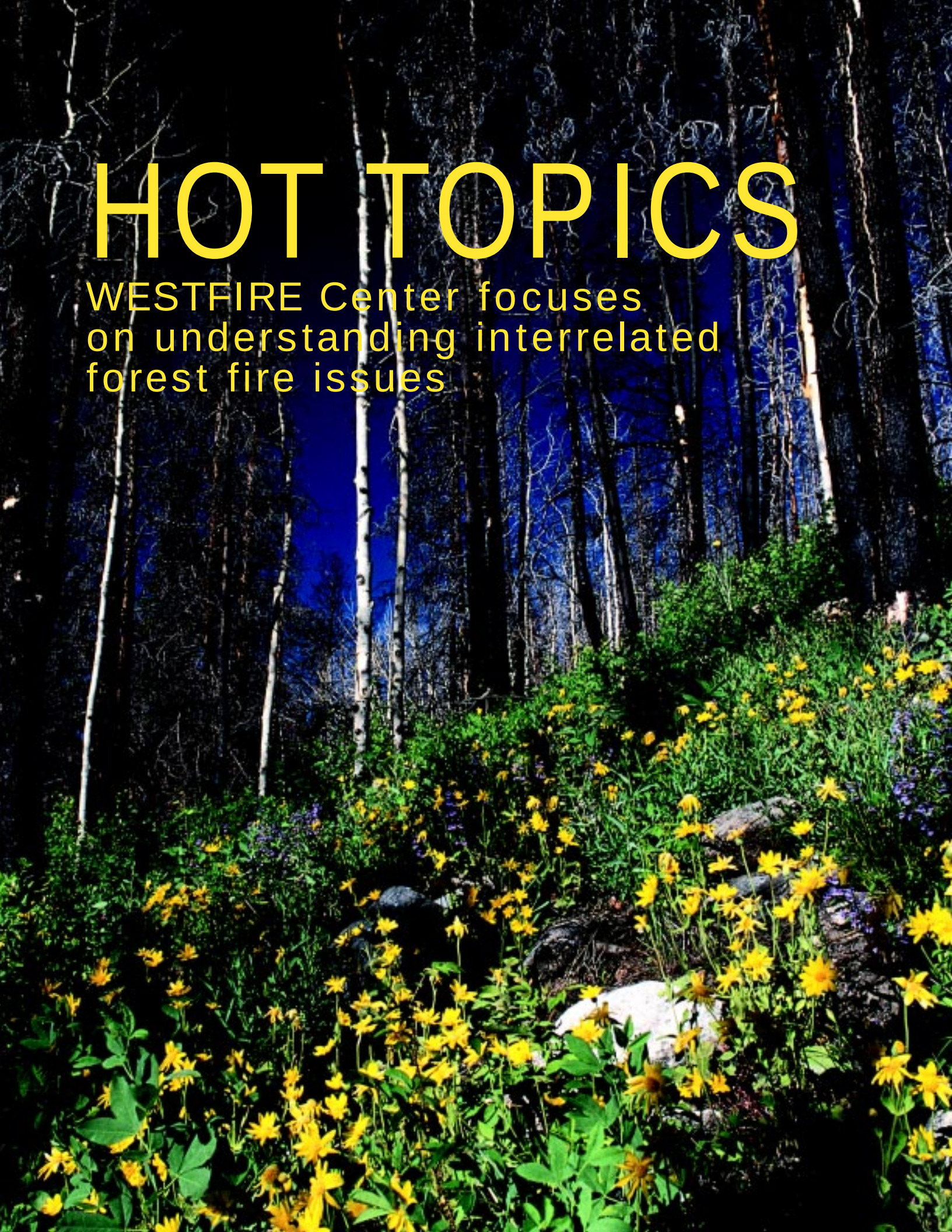
Knudson, Brown, and Stephens have established many of these sophisticated tools here at Colorado State. With them, they have found the general region on the mosquito chromosome that makes mosquitoes likely disease carriers. The bad news is that there are about two million sequences in this region. So, there's a lot more to do before they identify *the* gene that allows mosquitoes to do their dirty work.

While Knudson's research group focuses on mosquitoes, their overall goals are much broader. "What we learn from the mosquito project is directly applicable to agriculture," says Knudson."For example, we can use the same methods to find the genes that help a plant resist a particular disease."

Through collaborations with colleagues in soil and crop sciences, pathology, animal sciences, bioagricultural sciences and pest management, and microbiology, Knudson's group is applying its tools to the study of barley genetics, bacterial ring rot in potatoes, wheat resistance to Russian wheat aphid, and livestock projects. Brown says, "Keeping the different systems straight can be quite a job, but seeing our technology make contributions in other research areas is rewarding."

The Knudson team is part of the Arthropod-Borne Infectious Disease Laboratory (AIDL) at Colorado State. They also collaborate with scientists at the Centers for Disease Control laboratory in Fort Collins and the Arthropod-Borne Animal Disease Research Laboratory in Laramie, Wyo. Thanks to major grant funding from the National Institutes of Health and with additional support from the MacArthur Foundation, the U.S. Department of Agriculture, and the Colorado Agricultural Experiment Station, Knudson and his team have purchased sophisticated equipment, built labs, and established genomics tools previously unavailable at Colorado State. These tools enrich the environment at the University through the team's extensive collaborations.

Genomics may not seem relevant to our everyday lives, but it will profoundly affect our future. Says Knudson, "Genomics will impact our lives as dramatically as did the Industrial Revolution."



HOT TOPICS

WESTFIRE Center focuses on understanding interrelated forest fire issues

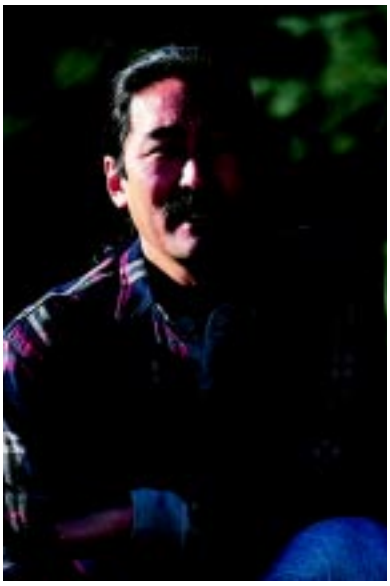
It's not a matter of whether a forest fire will strike any given wooded area, it's a matter of when. And while we can't control the whether and when of a forest fire, we can have some say over how severe that fire might be.

Phil Omi, professor of forest sciences and director of the Western Forest Fire Research Center (WESTFIRE) at Colorado State University, is working on that very topic.

Omi has focused on a systematic assessment of the effectiveness of fire mitigation treatments, such as mechanical removal and prescribed fire. By studying wildfire effects in both treated and untreated areas, he can evaluate how well certain treatments work.

That's not always as straightforward as it sounds. Fires in treated areas are not always less intense or less damaging than fires in untreated areas. There are many other variables that may affect severity: temperature, wind speed, the toll from insects or diseases, or how long ago the area was treated. Nonetheless, fuel removal reduces the severity of eventual wildfires. The bigger question is whether public agencies can treat large enough areas to effectively reduce the fire hazard.

Colorado State has become a leader in evaluating the cost/benefit side of fire mitigation, thanks to Omi and colleagues Doug Rideout in forest sciences and John Loomis in agricultural and resource economics. It is fairly simple to assign a value to saving timber or livestock grazing, two direct benefits of fewer or less damaging fires. But Colorado State's research has focused on benefits that are harder to assign a monetary value to. How much is wildlife habitat worth, especially for nongame and threatened or endangered species? What's the value of maintaining water and air quality from fewer or smaller fires? Most people would agree that these are significant benefits. Because they are not marketable commodities, however, there is no easy way to factor them into the cost/benefit decisionmaking process.



Cost/benefit analysis is becoming even more important as greater numbers of Americans build homes in or near forested areas. People and property in this urban fringe are at increasing risk from fires. In Colorado, these areas include the Front Range and Durango. Because this is private land, landowners bear much of the fire mitigation cost themselves. A sound economic basis for decisions on what, where, when, how, and how much to treat is as important to them as it is to managers of large forests.

Thinning often is recommended to reduce fire risk. Selling the resulting lumber would help landowners offset their costs. Unfortunately, there is not much demand for the small-diameter trees produced by this thinning. Selling it as firewood, an obvious option, is becoming less feasible, as more and more areas put restrictions on wood burning. Omi and Dennis Lynch, also in forest sciences, are looking into markets for these small-diameter trees.

There are demographic issues, as well. Are newcomers to forested areas aware of the consequences of choosing to live in or near a forest? How well do they understand fire management, fuel management, and even fire itself? What are the best ways to reach various audiences to educate them about the importance of fire mitigation practices? Omi and his colleagues are hard at work trying to answer these questions and, in the process, come to better understand how to communicate with people at risk from forest fires.

Luckily for Colorado, Omi and WESTFIRE understand that you can't control the whether and when of forest fires. Their research is predicated on controlling the severity through effective fire mitigation practices, cost/benefit evaluations, understanding conflicting perspectives and management goals, and improving communications with people at risk from fire.

A STAKE THROUGH THE HEART OF THE RUSSIAN WHEAT APHID

New varieties and growing techniques help producers defend their fields

Russian wheat vampire might be a better name for the Russian wheat aphid (RWA). This voracious pest sucks the lifeblood out of wheat and, with it, a farmer's profits. RWA first flew into the state in 1986. Since then, it has guzzled up more than $126 million in crop losses and spraying costs for Colorado's 14,000 wheat farmers.

Insecticides can hold this scourge at bay, but they aren't a permanent solution. Besides cost and environmental concerns, insects can develop resistance to chemicals used repeatedly.

Frank Peairs, professor of bioagricultural sciences and pest management, has spent the past 12 years looking for ways to control RWA. He and his colleagues are working on four separate but related avenues of attack.

One avenue, led by Peairs, has focused on cultural practices used for wheat production. RWA can live on certain weeds when wheat isn't available, so weed control can help reduce RWA numbers. In southeast Colorado, allowing cattle to graze on early stages of winter wheat can delay spring infestations. Proper fertilization can help wheat both resist and recover from RWA feeding. Plant spacing can help reduce the number of aphids in a field. Finally, adjusting planting dates can lessen spring or fall infestations in some locations. In barley, even something as seemingly insignificant as whether irrigation furrows run east to west or north to south can have an impact on the level of infestation.

RWA-resistant wheat varieties are a second approach. Jim Quick and Scott Haley, professors of soil and crop sciences, led this effort. Their efforts led to Halt, the first RWA-resistant, commercial variety of winter wheat in the nation. Halt was released to Colorado wheat growers in 1994. Unfortunately, Halt is suited only to certain parts of Colorado. Three more RWA-resistant varieties have been released since Halt came out in 1994 and a fourth should be available within two years. More varieties give growers more options to meet local growing conditions and market needs and still get the benefits of RWA resistance.

Unfortunately, the resistance in all these varieties is based on the same single gene. "Sooner or later, RWA will figure out how to get by that resistant gene," says Peairs.

This has led to the third aspect of the RWA effort. "One way to prevent RWA from overcoming resistance is to get two genes for resistance in the same plant,"says Peairs. "It presents a more challenging puzzle for the aphid to figure out." Nora Lapitan, professor of soil and crop sciences; Dennis Knudson, professor of bioagricultural sciences and pest management; and others are working to identify additional genes for RWA resistance in winter wheat. So far, they have identified seven genes that show RWA resistance.

The fourth part of the RWA project is an integrated dryland agroecosystem approach. Led by Gary Peterson and Dwayne Westfall, professors of soil and crop sciences, as well as Peairs, this approach looks at the overall production system on dryland farms. For example, a wheat-fallow rotation is the traditional way to raise dryland winter wheat. The researchers are testing a wheat-corn-millet-sunflower-fallow rotation. Four years out of this five-year cycle are devoted to plants RWA can't eat. The aphids either move on or die of starvation. This more intensive cropping system adds to farmers' overall profitability. It also provides an environment where natural predators can thrive and prey on RWA and other crop pests, which further reduces a farmer's dependence on chemicals. This overall system can incorporate one or more of the cultural practices identified by earlier research.

None of these tools, by itself, is the single stake a farmer can drive through the heart of this vampire of a pest. But used in various combinations, they can minimize infestations at little cost to farmers or the environment.

THE PIED PIPER OF

Research lets nature work for the farmer

You could call Rick Zimmerman, research scientist at the Rogers Mesa Research Center, the Pied Piper of Hotchkiss. But instead of piping rats out of town, he gets bad insects out of orchards. And instead of a flute, he uses the insects' own chemicals against them.

Take earwigs. They've been a real problem this year, especially in organic peach orchards. When he tried the biological insecticides Neem and Pyrellin, "They laughed at me," Zimmerman says. So, he wrote a whole new tune just for them. "During the day, earwigs like to hide out with their buddies. They release a chemical, or pheromone, so they can find each other." Zimmerman drilled holes in PVC pipe, baited it with wheat bran and assorted essential oils, and hauled away earwigs by the thousands. He's the one laughing now.

Then there's the codling moth. This is the number one pest of apples in Colorado, costing individual growers thousands of dollars every year.

When a female moth is ready to mate, she emits puffs of a sex pheromone to attract male moths. For some years now, apple growers have used pheromone-treated twist-ties in their orchards. These look very much like the ties you find on plastic bags of bread or produce – just bigger. But attatching them to individual trees is labor intensive and they can be expensive, up to $110 per acre per year for just the pheromone.

Zimmerman has been testing man-made "puffers" that emit clouds of this sex pheromone. This lays so many false trails for the hapless male moths that many die before they ever find a female to mate with. While the puffers cost $60 to $70 each, growers may need only two or three per acre. Puffers can last many years, needing only refills each year.

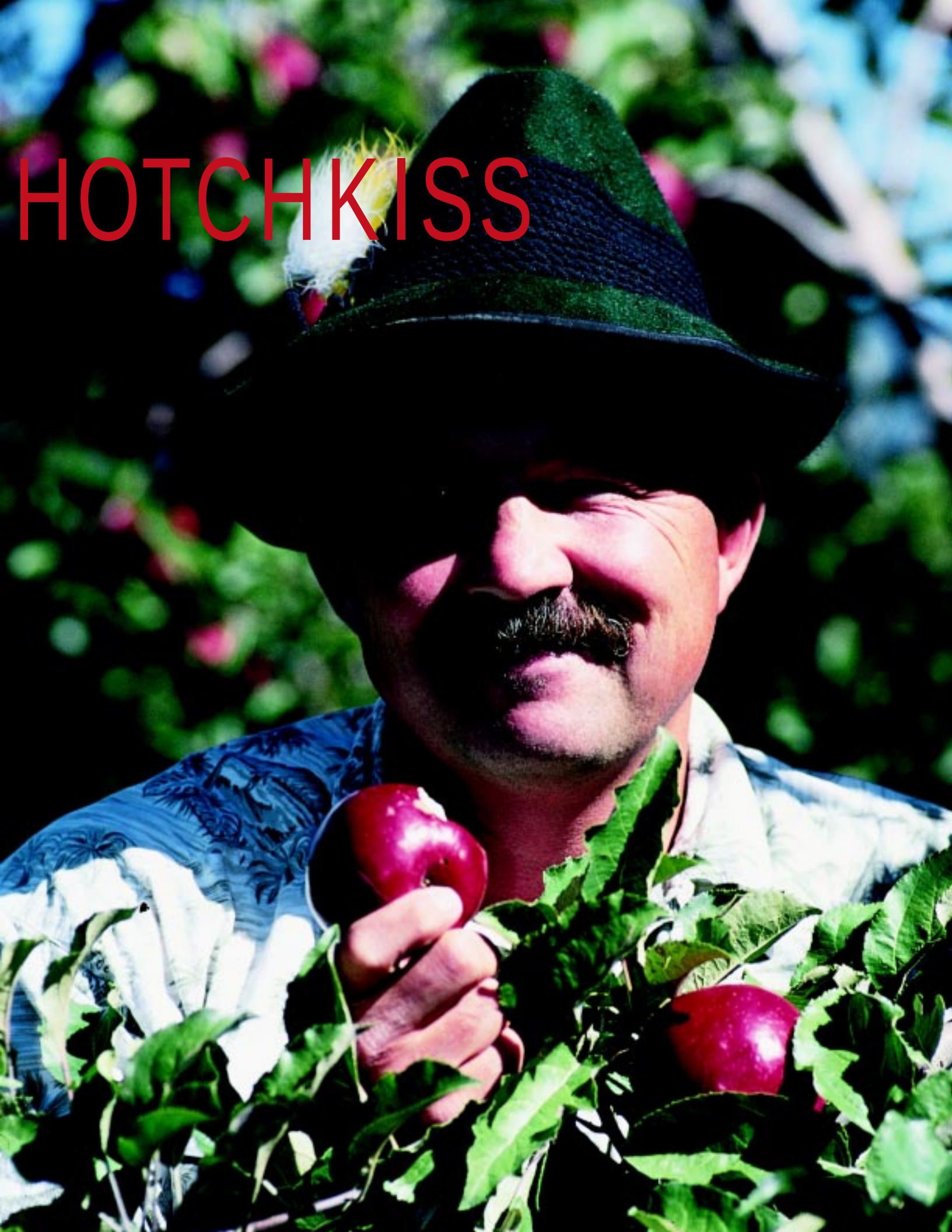
Pheromone-based pest management costs less than conventional programs, and it has a secondary benefit as well: It doesn't kill insect predators. Growers not only don't have to spray for codling moths, they don't have to spray as much for other pests either, such as aphids and leafhoppers, because insect predators are still alive to do their own number on the bad guys.

Pheromones aren't the only song in Zimmerman's repertoire. He also plants flowers to encourage beneficial insects. Syrphid fly larvae eat a lot of aphids. The adults, however, feed only on nectar and pollen. By planting flowers for the adults, Zimmerman thinks he can entice them to hang around the orchard longer and lay more eggs, which hatch into more larvae, which eat more aphids. "Ideally," he says, "something will be in bloom from April until September."

He's also trying out a species of parasitic wasp. Originally from Kazakhstan, it has parasitized up to 50 percent of the codling moths in other apple-growing areas. Unlike pheromones, this control method should also help reduce codling moths in urban areas adjacent to orchards.

Research into soil ecology is a natural next step for Zimmerman. Working with John Moore and Jennifer Doles at the University of Northern Colorado, as well as Colorado State's Jessica Davis, he wants to see what soil critters live in orchards, both organic and conventional, and in native or uncultivated areas. What are the populations of harmful and beneficial insects and other organisms? How can they be manipulated to reduce orchard problems? How does the soil food web affect the flow of nutrients to plants, and can that be turned to the grower's advantage?

"The whole idea," says Zimmerman, "is to get nature to work for the farmer. I've never met a grower that likes to spray. Insect and disease problems are biological in nature, and ultimately, that's how they'll be solved."


HOTCHKISS

THE X Y FACTOR

Researchers discover the secret of determining the sex of offspring

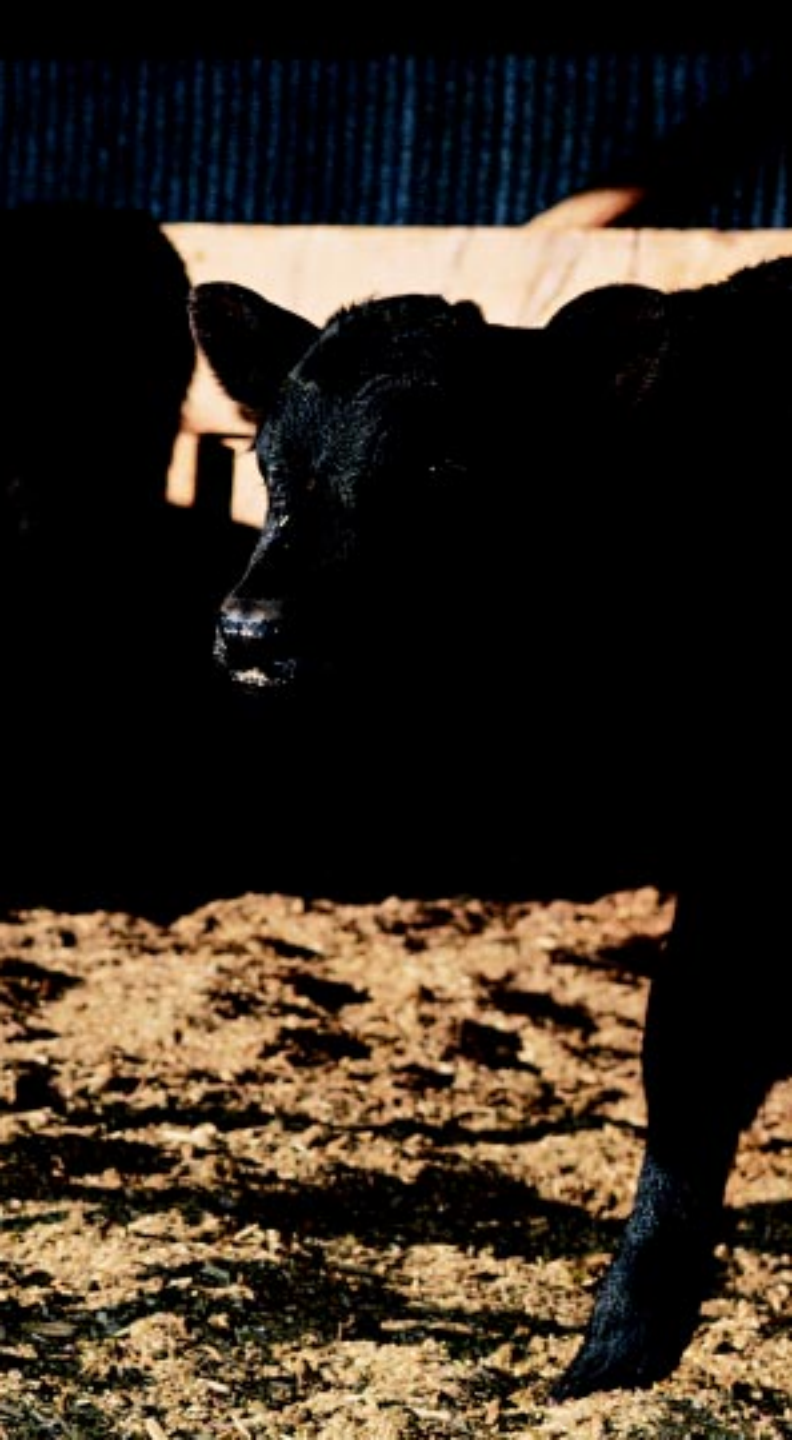
It may not be nice to trick Mother Nature, but that's exactly what George Seidel has figured out how to do. Seidel and his colleagues have discovered the key to choosing the gender of new life.

They can now dictate with 90 percent accuracy whether or not a calf will be a heifer (female) or a bull (male).

By sexing sperm, or sorting it by gender, animals can be artificially inseminated to bear one sex or the other depending on a producer's needs. When applied to livestock, this discovery gives producers an enormous edge. For example, a dairy farmer can ensure heifer calves, giving him more future milk cows for his herd.

"Sperm come with either an X or a Y chromosome. Eggs only come with an X chromosome," explains Seidel. "When life is conceived and those chromosomes merge, it's either XX for female or XY for male."

Most animals produce an equal number of X and Y sperm, creating a 50-50 chance for each gender to be



conceived. Seidel says X sperm are minutely bigger, but it is a very slight difference.

"If you think about it, you want the X and Y sperm to be the same because if one was much bigger than the other, it would be much slower. A slower sperm would have less chance of fertilizing an egg, so you wouldn't get a 50-50 mix of each gender in the population," says Seidel. "Nature goes to great lengths to make sure they are as identical as possible, which makes it very difficult to tell one from the other."

But by a fluke, the U.S. Department of Energy discovered a way. Scientists in the nation's top weapons lab in California routinely monitor the health of their employees, who are exposed to radiation, lasers, and bombs. Typical checks include drawing blood, but technicians worried about the cells of the next generation – the children of their employees. How would their parent's work environment and exposures affect them? As a result, the technicians started collecting sperm. Their high-tech equipment allowed them to look at the sperm in detail, and they discovered that there were two kinds: male and female.

Eventually, the Department of Energy and the U.S. Department of Agriculture started working together to apply this finding to farm animals. They learned to sort male sperm from female, but their early methods were harsh and killed the sperm. Eventually, they discovered the more effective method of dying the sperm and passing them through a laser. Female sperm contains about 4 percent more DNA, making the dye slightly brighter under the laser.

But even after several years of refining the technique, sorting is still a slow process. The present process can sort about 1,500 sperm of each sex per second, a drastic improvement over the earliest tries, which could only sort 100. But traditional artificial insemination requires millions of sperm to ensure conception; for pigs, it requires billions. At that rate, says Seidel, it can take days to sort enough sperm to impregnate one animal, and sperm is hard to keep alive outside of a body.

Clearly, a new strategy was necessary.

"I thought to myself, 'It only takes one sperm to fertilize an egg. If you do everything just right, maybe you could be successful with fewer sperm,' " says Seidel.

So, Seidel and several other researchers ran a series of experiments to combine the sperm sexing technology with improved artificial insemination technology. "The combined process works very well in some situations," says Seidel. "Our initial pregnancy rate ranged between 0 to 45 percent. Normal rates for artificial insemination is 60 percent. We're now within 10 percent of normal artificial insemination pregnancy rates."

Research shows that animals born of sexed semen are normal, giving producers the edge Seidel was hoping for. Research continues, conducted in part by a private company, XY Inc., based in Fort Collins, formed to make this technology available to producers.

"My objective is to make the use of sexed semen economical and practical for producers," said Seidel. "It can make ranching more efficient and, ultimately, benefit the consumer."

Seidel said he expects the technology will be available to producers by the beginning of 2001.

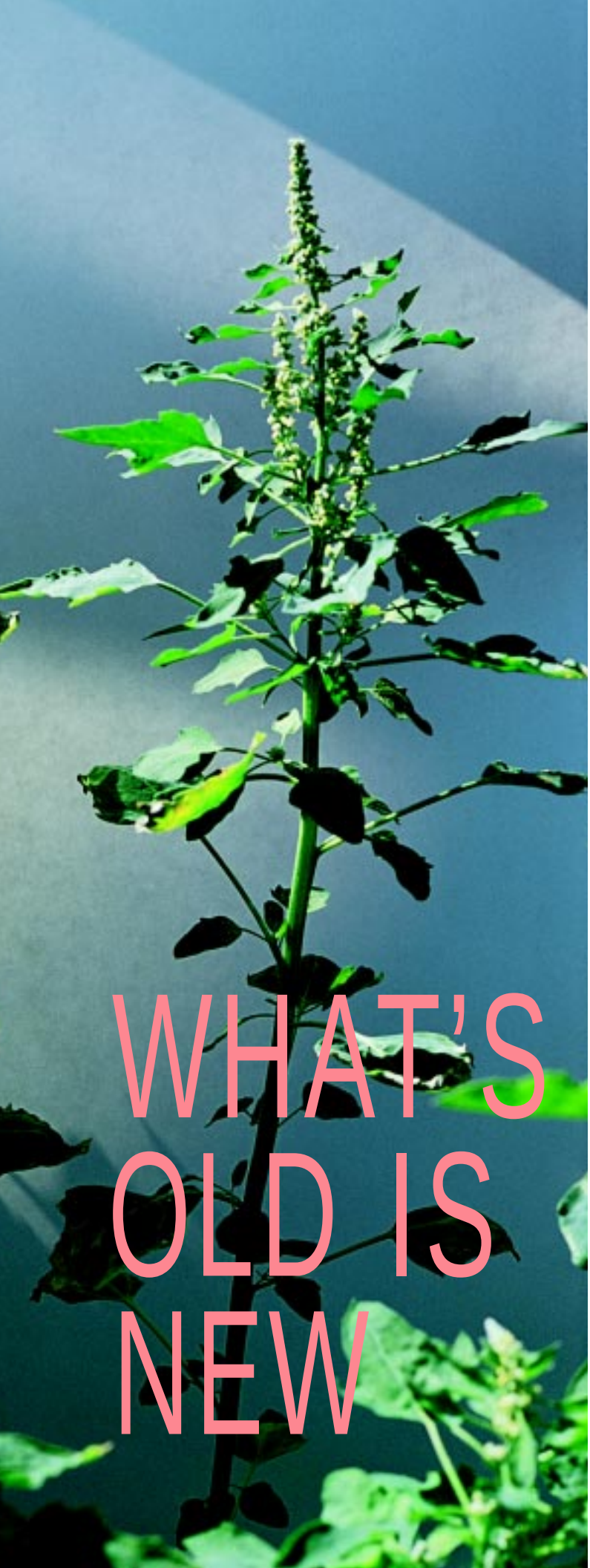
It's been said that all things come back into style if you wait long enough, but the 5,000-year wait for the return of quinoa is a longer cycle than most.

This ancient, sacred crop of the Incan culture was recently rediscovered, and as it is becoming known for its health value, it is becoming a more popular crop for Colorado farmers. Sarah Ward, a plant breeding and genetics researcher for Colorado State University Agricultural Experiment Station, became charmed by quinoa's history when she spent several years in Ecuador with the British Volunteer Program. Ward has been one of several people responsible for reviving interest in this native South American crop.

Although quinoa is just now being noticed in North American health food stores, Ward says that our perception of it as a "new" crop isn't appropriate: Quinoa was one of three main crops in the Incan Empire, along with potatoes and corn. Traces of the crop have been found in ruins dating back thousands of years. Traditionally, it's been boiled like rice, popped like popcorn, or ground into flour.

"I became fascinated with quinoa because it got lost, unlike corn and potatoes," said Ward. "I have two theories about its disappearance. One is that quinoa seeds don't last very long, especially if they get wet. When the Spanish returned to Europe from the New World, the quinoa seeds would likely not have survived the trip. We also know that the Spanish imposed Catholicism on the Incan people, and part of that practice would have been to destroy all vestiges of native Incan religion. Quinoa was a sacred crop, known as the "mother grain," or the ultimate fertility symbol. It could not have been grown, on penalty of death, and only

Nutritious quinoa proves to be an excellent crop for Colorado growers



WHAT'S OLD IS NEW

survived in remote villages where the Spanish didn't find it."

In those remote villages, a Bolivian scientist started collecting the crop for research in the 1960s. Then, in the 1980s, another scientist introduced quinoa to the United States and Colorado.

When cooked, the tiny sesame-seed sized grain swells to about half the size of a grain of rice. "It's tremendously healthy," says Ward. "It's high in protein – about 15 percent – and high in lysine, an amino acid that's rarely found in plants. That makes quinoa an excellent source of lysine for vegetarians. It also contains no gluten, making it an alternative to wheat. Quinoa leaves may be eaten as a salad, too, and are high in vitamin C. The leaves taste like spinach, and the grain is slightly sweet and nutty — somewhat like wild rice."

Because the crop is so ancient and so little is known about it, Ward began by researching its genetic makeup. With that information, she's working on varieties that can be grown more successfully in Colorado's climate, developing hybrids with a shorter stem, shorter growing season, higher yields, and larger, whiter seeds. Ward has been DNA fingerprinting varieties to identify parent lines for hybrids, but she has no way of knowing how old each variety she's working with may be.

Quinoa is a tough crop to cross-pollinate because when in bloom, each quinoa stem produces thousands of tiny flowers. Only by crossing varieties with naturally occurring mutants found in the field has Ward been able to begin producing hybrids. She's also working to build a hybrid without a saponin layer. Saponin is a bitter, hard shell around the seed that gives the plant a defense against birds and insects that are pests in its native area.

The crop is already very drought tolerant, so it's successfully grown in dryer areas of Colorado, such as the San Luis Valley. It can survive on as little as 8 inches of annual moisture and thrives on 10 to 12 inches.

"About 90 percent of quinoa found in health food stores in the United States is imported from Ecuador or Bolivia," said Ward. "So the United States product is only meeting a fraction of the market demand. Quinoa is still a niche market in health food stores, but it's becoming more and more popular."

THE WEATHER BUG

Researcher is itching to develop a more reliable long-term forecasting system

If a butterfly flaps its wings in Iowa, will it storm in Colorado?

Maybe.

But Bill Cotton can tell you that the one has little to do with the other.

Cotton, an atmospheric science researcher and professor at Colorado State University, dedicates his time to more reliable methods of predicting rain or shine in Colorado.

Using the combined computing power of 25 Pentium computers strung together, Cotton is developing a comprehensive, detailed forecasting system that will predict Colorado weather as much as six months in advance. Granted, six-month forecasts won't be pin-point accurate, but they will give agricultural producers and reservoir managers a good general idea of how hot and how wet a summer may be.

That's important. Agriculturists rely on the weather to nourish grassland for grazing livestock or to help irrigate crops. They not only rely on annual rainfall in the spring and summer, they also rely on reservoirs to hold winter snow runoff to be used as irrigation water in dry, hot summer months. For those who gamble with Mother Nature when managing water resources, Cotton's forecasts can mean the difference between a productive year and a long, hot, dry one.

"These forecasts will be long term enough to give such people as reservoir managers and producers enough time to gauge how much water to preserve or how much water they'll have to irrigate crops," says Cotton.

Establishing a forecast is critical to reservoir managers. The winter of 1983 was a good example, says Cotton. There was little snow pack, leading producers and reservoir managers to expect poor run-off. Then, much to their surprise, late March brought heavy snow and rain. Unfortunately, the reservoirs were kept at a high level in anticipation of a dry year and, as the late moisture came in, flooding and erosion caused millions of dollars of damage in many areas.

Cotton's forecasting system is part of the Regional Atmospheric Modeling System (RAMS) developed by the Colorado State University Agricultural Experiment Station. The system allows Cotton to make more comprehensive 24- to 48-hour forecasts than those made by the National Weather Service because it predicts weather variables in a tighter geographical region, showing more detail by pin-pointing conditions every seven miles or so. The National Weather Service system only looks at regional conditions and makes generalizations.

The RAMS' tighter grid system allows Cotton to capture conditions from small storms in specific areas and forecast wind, temperature, evaporation, precipitation, humidity, and other variables that often slip through the National Weather Service's larger grid. These specific variables can help producers gauge how to create an optimum atmosphere for their crops to grow. For example, with this information a producer can find the balance between how much of his irrigation water is evaporating into the atmosphere and how much is nourishing his crop.

Using those variables, historical data, and such complicated factors as sea surface temperatures, snow

cover, and weather patterns, Cotton can also make general forecasts several months ahead, especially when gauging snow fall, snow pack, and snow runoff for reservoir storage.

"We try to establish soil moisture, vegetation, and many other details in order to make long-term forecasts," said Cotton. The short-term, high-resolution forecasts can even look at the effects a city has on the weather, with lawns being watered and the numerous other variables created by humans – or the flap of a butterfly's wings.

There's nothing quite like a thick, juicy, sizzlin' steak cooked to perfection. But just what is it that makes some steaks taste better than others?

Daryl Tatum, a meat quality researcher for Colorado State University's Agricultural Experiment Station, knows a few tricks to make a steak dinner a true treat.

Tatum and two other Colorado State animal science professors, Keith Belk and Gary Smith, have improved the taste, shelf life, and integrity of meat through their research. They have focused on beef in an effort to help cattle ranchers regain part of the food market. Beef's share of the market has dropped drastically since the 1980s in favor of chicken and pork.

"We want to improve the quality of beef that's in the grocery stores and restaurants," says Tatum. "We focus on taste – how

tender, juicy, and full of flavor the meat is. Taste is a consumer's primary driver, and beef is relatively expensive compared to chicken and pork. For a consumer to pay extra money for beef, it has to perform up to their expectations. It's just like building a car – if it's not worth the money, no one's going to buy it. We want to help beef producers stay profitable and in business."

The team has discovered that there are several things that can impact the quality of a meal: the animal's breeding, what it eats, the amount of stress the animal experienced, and how the carcass is treated.

It begins with genetics: Some varieties of cattle taste better than others. Also, some cattle have calmer dispositions, and calmer animals produce more tender meat than wilder ones do.

Next, Tatum's group has identified quality control points to help cattle produce the best possible beef for their breed. "Small changes in management practices can make a difference in the quality of meat produced," says Tatum. "We recommend putting beef cattle on a high-grain diet about 100 days before harvest. You can really improve the taste and tenderness by boosting energy intake during this period."

The way preventative antibiotics or vaccines are administered can also make a difference. When cattle are given an injection in the muscle, the needle often causes a lesion and scar tissue-like toughness in a muscle. A producer can protect the quality of his product by injecting such medicine into areas such as the neck rather than the hip, where it would ruin the quality of a steak or roast. Lesions from needles can last up to 18 months – about the time a calf would be mature enough to be harvested. Overuse of growth-promotants also can cause beef to be tough.

Tatum also has found that certain practices after meat is harvested can make it more tender. For example, Tatum says muscles contract and shorten as rigor mortis sets in, making them more dense and tough. Electrical currents can be used to make muscle tissue relax after harvest, ensuring more tenderness.

Injection treatments are another way to improve quality. Injecting water, sodium lactate, or phosphorus into carcass muscle can help prevent overcooking, which can hamper the taste of beef. "Many consumers overcook beef," says Tatum, "either because they are concerned about food safety or they just don't know how to properly cook meat. These injection treatments also make the meat juicy and more flavorful, giving it a slightly salty, more beefy taste and help ensure that steak your mouth is watering for is cooked to perfection."

COOKING UP A BETTER STEAK

Researchers develop methods for producing more tender, tasty, and juicy beef

BUILDING A (BIO)SOLID PARTNERSHIP

Researchers find biosolids produced by cities can be an effective crop fertilizer

With the Front Range's rapidly growing population, city and county officials are faced with many challenges. One of those challenges is disposing with municipal biosolids – residential and commercial waste. Ken Barbarick, a professor of soil sciences and researcher for the Agricultural Experiment Station, has looked for ways to use biosolids as a resource.

Barbarick started investigating the use of biosolids as an agricultural fertilizer in the early 1980s when Tom McBride, a Colorado State University Cooperative Extension agent in Adams County, was contacted by Englewood and Littleton city officials who were expanding their waste treatment facility.

"Those cities wanted to be proactive about the environment and ease the public's mind about the use of this kind of waste as a fertilizer for dryland crops," said Barbarick. "They've supported our research for 17 years. We've gathered facts on both short-term and long-term effects, and our research has found no problems with the conscientious agricultural use of biosolids."

Barbarick and colleague Ed Redente, a professor of rangeland ecosystem sciences, also have used biosolids to help restore an area in Jefferson County burned in a wildfire. The biosolids helped restart the ecosystem when added to plots replanted with native grasses. These plots recovered dramatically quicker than areas without biosolid applications.

Using biosolids as a fertilizer safely recycles waste, says Barbarick, after it has been pre-treated to kill diseases carried by humans. In Colorado, more than 80 percent of municipal biosolids go toward a beneficial use with industries such as agriculture or on disturbed lands. The national average for municipal waste recycling, says Barbarick, is more like 50 percent. The biosolids that aren't recycled back into the environment often end up in landfills.

Biosolids have proven to be an effective fertilizer; more effective, in fact, than animal manure traditionally used on crops for its nitrogen content, says Barbarick. That's because municipal biosolids are more stable than animal waste, so they break down more slowly. That allows more control of the rates of nutrients going into the soil from the waste, which helps preserve the quality of soil and the water supply from an unhealthy overload of minerals or other elements.

After application to soil, biosolids release plant nutrients such as nitrogen, phosphorus, zinc, and iron that are vital to produce a healthy crop. Biosolids must be applied to soils at an agronomic rate – a rate determined to match the nutrient needs of the crop grown. A proper application rate is essential to prevent buildup of excess nitrogen, which is mobile in soils and can leach downwards to contaminate groundwater.

The application of biosolids to soils used for crop production is governed by regulations imposed by the Colorado Department of Health and the U.S. Environmental Protection Agency. These regulations have been developed to ensure that biosolids have been treated to reduce disease-causing microbes and to minimize odor and nuisance problems after application. In addition, the biosolids are analyzed for nutrients, metals, and trace elements. The Agricultural Experiment Station's research program has monitored the uptake of nutrients and metals such as cadmium, zinc, and lead in winter wheat for the past 15 years. Properly managed biosolids application has safely improved the quality of the winter wheat crops grown.

"The use of biosolids as a fertilizer is part of a cycle," says Barbarick. "Agriculturists need nutrients for crops, the crops go to the city to be consumed, and the city's waste goes back to the land for crops. Farmers deserve credit by using their land to help cities recycle their waste and for being environmentally conscious enough to use biosolids. This is a partnership between farmers and city dwellers."

Colorado Agricultural Experiment Station Contributors

Colorado State University Colleges and Departments

College of Agricultural Sciences

Department of Agricultural and Resource Economics
Department of Animal Sciences
Department of Bioagricultural Sciences and Pest Management
Department of Horticulture and Landscape Architecture
Department of Soil and Crop Sciences

College of Applied Human Sciences

Department of Design, Merchandising, and Consumer Science
Department of Food Science and Human Nutrition
Department of Human Development and Family Studies

College of Engineering

Department of Atmospheric Science
Department of Chemical and Bioresource Engineering
Department of Civil Engineering

College of Liberal Arts

Department of Sociology

College of Natural Resources

Department of Earth Resources
Department of Forest Sciences
Department of Rangeland Ecosystem Science
Natural Resource Ecology Laboratory (NREL)

College of Natural Sciences

Department of Biology
Department of Chemistry

College of Veterinary Medicine and Biomedical Sciences

Department of Anatomy and Neurobiology
Department of Clinical Sciences
Department of Environmental Health
Department of Microbiology
Department of Physiology

Research Centers

ARDEC (Agricultural Research, Development, and Education Center)

Reg Koll, Manager
(970) 491-2405
4616 NE Frontage Road
Fort Collins, CO 80524

Arkansas Valley Research Center

Frank Schweissing, Superintendent
(719) 254-6312
27901 Road 21
Rocky Ford, CO 81067

Eastern Colorado Research Center

David Schutz, Manager
(970) 345-6402
26206 County Road 57
Akron, CO 80720

Fruita Research Center

Shane Max, Manager
(970) 858-3629
1910 “L” Road
Fruita, CO 81521

Mountain Meadow Research Center

Joe Brummer, Superintendent
(970) 641-2515
Box 598
Gunnison, CO 81230

Orchard Mesa Research Center

Shane Max, Manager
(970) 434-3264
3168 B .5 Road
Grand Junction, CO 81503

Plainsman Research Center

Kevin Larson, Superintendent
(719) 324-5643
P.O. Box 477
Walsh, CO 81090

Rogers Mesa Research Center

Shane Max, Manager
(970) 872-3387
3060 Highway 92
Hotchkiss, CO 81419

San Juan Basin Research Center

Beth LaShell, Interim Manager
(970) 385-4574
18683 State Highway 140
Hesperus, CO 81326

San Luis Valley Research Center

Tom Sanderson, Manager
(719) 754-3594
0249 E Road 9 North
Center, CO 81125

Southwestern Colorado Research Center

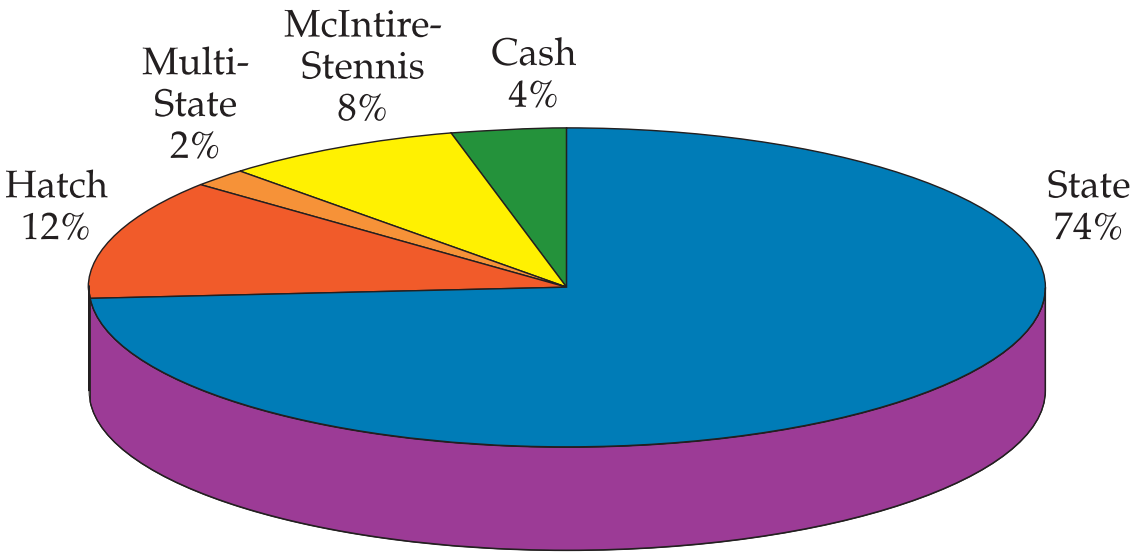
Mark Stack, Manager
(970) 562-4255
16910 County Road Z
P.O. Box 233
Yellow Jacket, CO 81335

Colorado Agricultural Experiment Station Funding for Fiscal Year 1999-2000

The Agricultural Experiment Station at Colorado State University is funded by appropriations from the Colorado legislature through the Colorado Commission on Higher Education, appropriations from the federal government through the United States Department of Agriculture, and self-generated income through the sale of commodities. The relative amount of each funding source is shown in the chart.

- State – funds appropriated by the Colorado legislature and allocated to Colorado State University by the Commission on Higher Education.
- Hatch – funds appropriated by the federal government to each land-grant university for support of a base research program in agriculture and natural resources. These funds are authorized by the Agricultural Research, Education and Extension Reform Act of 1998 and administered by the Cooperative States Research, Education, and Extension Service of the United States Department of Agriculture. The funds are prorated to each state based on a formula that includes several factors such as rural population, number of farms, and so forth.
- Multi-state research – a portion of the Hatch funds are mandated by Congress to be applied to research problems that are regional in nature and involve the efforts of several states. Funds are administered the same as Hatch funds.
- McIntire-Stennis – funds appropriated by the federal government to support research in forestry and forest resources. Funds are administered the same as Hatch funds.
- Cash – funds originating from the sale of goods and services associated with Agricultural Experiment Station programs. Commodities sold include crops and livestock, which are by-products of applied research programs conducted at research centers.

In addition to the above direct funding sources, scientists supported by the Agricultural Experiment Station are active in securing contract and grant funding from numerous private sources, as well as state and federal agencies. In the 1998-1999 fiscal year, contract and grant funding from these external sources contributed in excess of $22 million of support to our research programs.

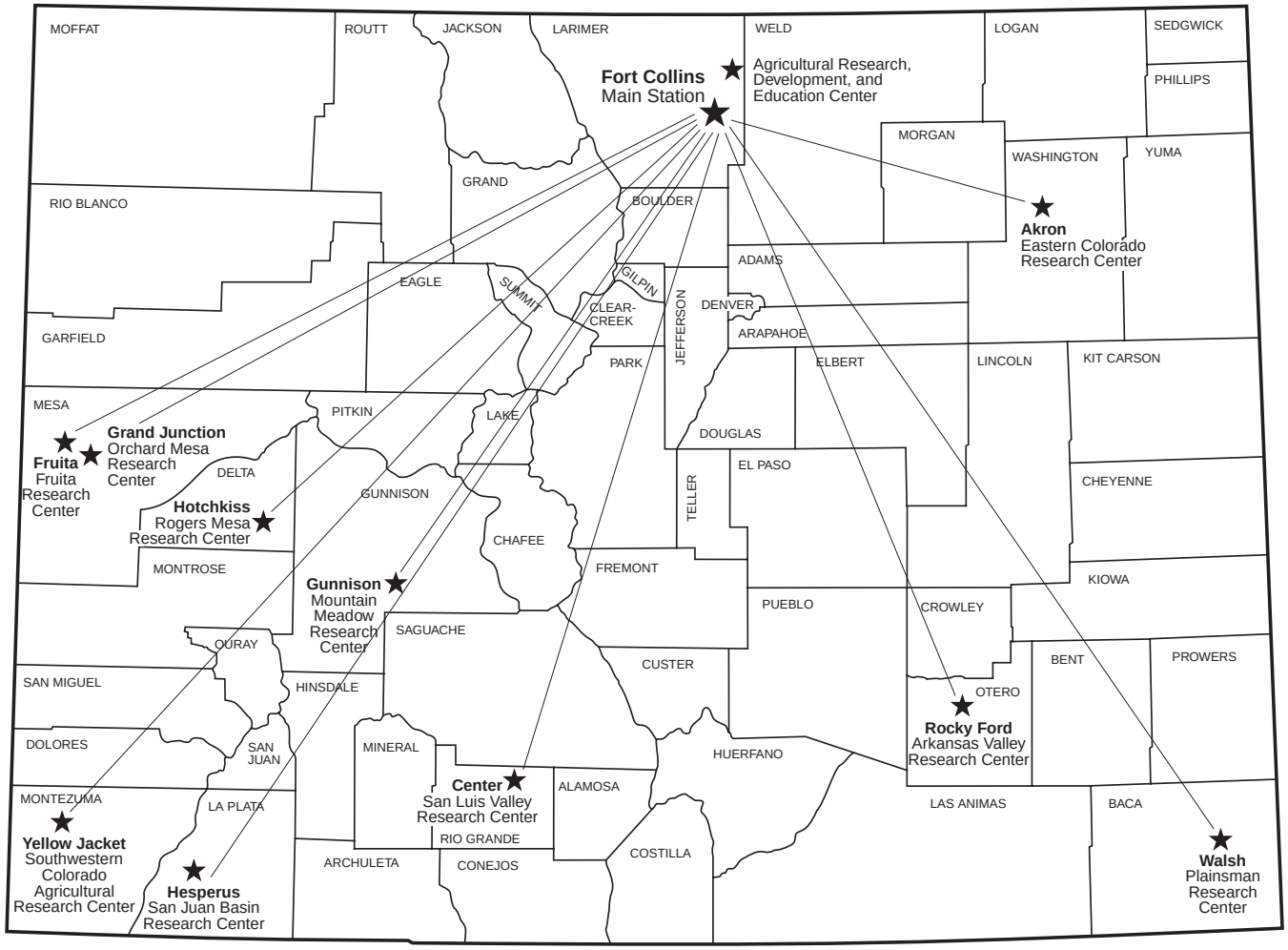


Total Budget: $12,456,165

Colorado Agricultural Experiment Station Annual Report 1999

Colorado State University

Colorado Agricultural Research System



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E-mail: aes@vines.colostate.edu
Web: http://www.colostate.edu/depts/AES

Editors:	Barbara Dennis, Mark Minor, Jeannine Kline
Writers:	Karen Holman, Dell Rae Moellenberg
Photography:	Bill Cotton
Illustration:	Monte Moore
Design:	Dale Rosenbach, John Goldie
Production:	Sandy Thode

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