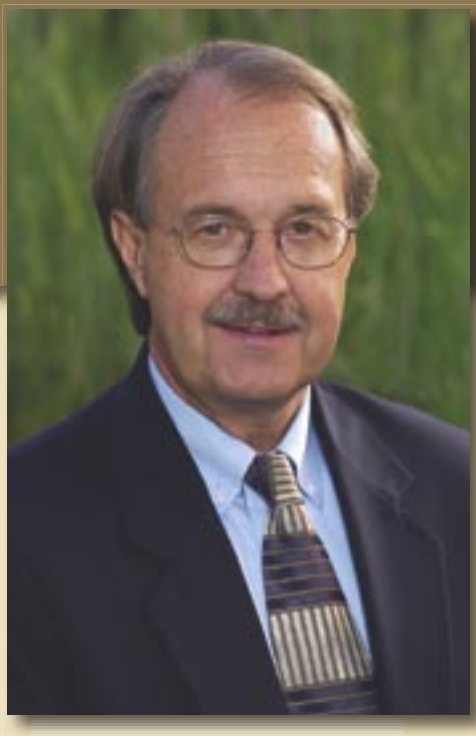

Annual Report

Colorado Agricultural Experiment Station, 2003

"We are proud of our faculty and their abilities to conduct relevant and important research."

This annual report summarizes the results obtained by a selected group of the more than 150 ongoing research projects supported by the Agricultural Experiment Station at Colorado State University.

The Agricultural Experiment Station is an integral component of Colorado State University, your land-grant university, and it is committed to conducting research based on the agricultural and natural resources needs of the people of Colorado. Our mission is to support research leading to an agriculture that is economically viable, environmentally sustainable, and socially acceptable. The Agricultural Experiment Station research efforts extend across the entire campus involving faculty and staff from more than 20 academic departments in 6 colleges. In addition to projects conducted by faculty located in Fort Collins, we have a network of off-campus research centers conducting research to meet agricultural production needs in different regions of the state. To address the complex problems facing agriculture, it is essential that academic departments and off-campus research centers work in concert with each other to solve problems through interdisciplinary efforts.

This past year has been a difficult one for the Colorado Agricultural Experiment Station due to reduced state funding. Proportional state budget cuts taken by higher education if applied to the research programs since fiscal year 2002 would amount to more than 23 percent in funding reductions. This large a reduction was not deemed feasible; therefore, Colorado State University provided additional support to limit the cumulative program reduction to 18 percent, or $1.62 million. These budget reductions are permanent decreases in funding, so long-term changes are required in programs located in academic colleges and departments at Colorado State in Fort Collins as well as at off-campus research centers.

In developing a plan, the Colorado Agricultural Experiment Station placed emphasis on the following: (1) support priority research programs central to the CAES mission; (2) retain faculty, research scientists, and research support personnel; (3) reduce operating expenses; and (4) maintain research centers and facilities that are necessary to support the research programs of the faculty and research scientists located both on- and off-campus. With this magnitude of funding reduction, it was necessary to eliminate vacant faculty positions, terminate support positions, reduce operating expenses, and close the Mountain Meadow Research Center. In spite of these challenges, our faculty and staff remain dedicated to providing relevant and quality research programs.

Many of the research projects described in this report receive significant support from state, regional, and federal funding agencies. Each year, the Colorado Agricultural Experiment Station compiles a report on external funding of our agricultural and natural resource research program. The total external funds received by our faculty exceed $20 million per year. Thus, funds provided by the state of Colorado leverage at least a two-fold increase in external support for our research programs. We are proud of our faculty and their abilities to conduct relevant and important research.

I hope you enjoy this report. Please contact me if you have any questions concerning the research program supported by the Agricultural Experiment Station at Colorado State University.

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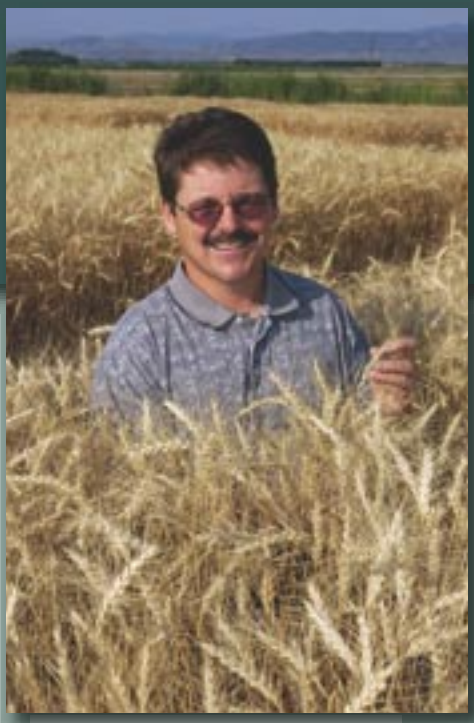
Colorado State University

Knowledge to Go Places



Forty Years of Experience

Wheat Breeding and Genetics Program Celebrates 40 Years of Service

Wheat is the backbone of dryland farming in eastern Colorado.

Scott Haley, associate professor of soil and crop sciences, is far too young to have 40 years of personal experience in the business of wheat breeding. As the fourth wheat breeder to direct Colorado State University's Wheat Breeding and Genetics Program, however, Haley knows that the foundation of his program was laid by the hard work, perseverance, and creativity of the breeders and researchers that went before him. Established in 1963, Colorado State's Wheat Breeding and Genetics Program conducts basic and applied research on the development of improved wheat cultivars with specific adaptation to the difficult growing conditions in the central High Plains region.

Since its inception, the Wheat Breeding and Genetics Program has released more than 20 improved wheat cultivars, and University-bred wheat cultivars now account for roughly 60 percent of Colorado's 2.6 million acres of wheat. This figure is drastically different from the mid- to late-1990s, when a single cultivar from Texas (known as TAM 107) dominated the landscape in eastern Colorado.

Wheat is the backbone of dryland farming in eastern Colorado. More Colorado acres are planted with wheat than any other crop, but wheat is traditionally a crop with low economic returns. Development of improved wheat cultivars serves a vital function for the wheat industry in Colorado by reducing costs of wheat production, minimizing or eliminating the need for chemical pesticides, and providing improved wheat marketing options. In partnership with the Agricultural Experiment Station, Colorado wheat farmers enthusiastically support the wheat breeding research at Colorado State University.

Colorado wheat must be able to withstand stresses that are somewhat different from those found in other areas of the Great Plains. Colorado is located on the western edge of the nation's great winter wheat breadbasket, and the state's dry conditions and high temperatures often reduce yields and adversely affect processing quality. At the same time, the lack of moisture makes Colorado winter wheat less prone to certain diseases and pests.

However, the Russian wheat aphid has been a persistent pest of Colorado wheat since 1986. The small, pale green, spindle-shaped insect damages wheat by sucking sap from and injecting toxic saliva into the leaves. The aphids prevent young wheat leaves from flattening out, and the insects live within the tightly curled leaves, protecting them from the weather and insecticides. Since the original strain of Russian wheat aphid arrived in Colorado, it has cost wheat growers in the state more than $132 million in crop losses.

A large component of Colorado State University's wheat breeding effort in recent years has been directed toward rapid deployment of genetic resistance to Russian wheat aphid. At the time of the pest's arrival, no wheat cultivars in the Great Plains (or the entire United States, for that matter) had resistance to Russian wheat aphid. Since 1994, however, several improved cultivars carrying resistance to Russian wheat aphid have been released by Colorado State University through a partnership with the Colorado Wheat Administrative Committee and the Colorado Wheat Research Foundation. Funding from the Agricultural Experiment Station has been instrumental in identifying, developing, and investigating strains of wheat resistant to Russian wheat aphid. Development of Russian wheat aphid-resistant cultivars provides wheat

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producers in Colorado and the west-central Great Plains with an effective, economical, and environmentally-sound means of mitigating economic losses from Russian wheat aphid.

Resistance to Russian wheat aphid is only one component in producing a quality superior wheat cultivar. Wheat breeding is a team effort requiring the expertise of many people from many diverse disciplines. Wheat breeding research at Colorado State University relies on an impressive network of field, greenhouse, and laboratory facilities. In the field, Haley and his team of researchers identify plants with desirable traits. Crosses are made and growth is studied in greenhouses. Insect resistance also is evaluated in greenhouse environments under the supervision of Frank Peairs in the Department of Bioagricultural Sciences and Pest Management. In Colorado State's newly-renovated Wheat Quality Laboratory, milling, dough mixing, and test baking of bread and noodles is done. A multitude of different criteria are important to wheat processors and the end-use industry, and the Wheat Quality Laboratory houses a variety of highly specialized equipment to evaluate experimental wheat cultivars for these criteria.

All this effort is directed towards the dream of producing a perfect wheat cultivar. "Although I can readily envision the ideal wheat cultivar, I expect that I will never find it. Compromise is definitely the name of the game," Haley says. Wheat producers are looking for cultivars that emerge well in the fall, don't fall over or shatter before harvest, tolerate multiple climatic stresses, and produce high yields with superior processing quality.

"There are so many traits that are desirable to producers, as well as to the processing industry – and an immense number and combination of genes control these traits. The wheat genome is incredibly complex, and combining all the necessary genes into a single package is virtually impossible with current technologies. Fortunately, I am part of a great community of wheat researchers, and we will continue to work toward these goals."

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The DNA of Wheat

Wheat has an incredibly large genome. Wheat is polyploid, which means that, hundreds of years ago, two species found in nature crossed and produced what is now known as Durham wheat; then, a third species hybridized with the first two to produce bread wheat. As the wheat genome is so complex and wheat is a public sector crop that tends to be a low-value crop, sequencing the wheat genome probably is not going to happen soon, but DNA markers have been identified for a few characteristics such as Russian wheat aphid resistance.

However, researchers are facing a new challenge. A new biotype or strain of the Russian wheat aphid was discovered in Colorado fields this year. As yet, genetic resistance against this biotype has not been identified in wheat plants.

Calculating Water Use

Evaluating the Accuracy of Consumptive Use Estimates in Mountain Meadows

Accurate estimates of consumptive irrigation water use are essential for administration of water.

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Water is a limited commodity in the western United States, and accurate estimates of water used in irrigation are necessary for administration of water in the region. In the upper Gunnison River Basin, Colorado State University professor of soil and crop sciences Dan Smith is researching forage water use.

Smith, with funding from the Agricultural Experiment Station and the Upper Gunnison River Water Conservancy District, is working with research scientist Joe Brummer of the Western Colorado Research Center and graduate student Darcy Temple to find a simple yet accurate method for determining the consumptive use of water in irrigated mountain meadows. "Consumptive use is the portion of the irrigation water applied to meadows that doesn't return to the stream system," Smith explains.

Accurate estimates of consumptive irrigation water use are essential for administration of water in Colorado and other western states because irrigation accounts for 80 to 90 percent of the region's total consumptive use. Colorado's allowable use under interstate compact agreements, like the Colorado River Compact, largely is attributable to irrigation. In addition, when irrigation water rights are changed to other uses, only the consumptive use can be transferred.

There are several methods for calculating consumptive use. All are based on measures of weather variables such as temperature, humidity, wind, and solar radiation. The most accurate methods require data for all four of these weather variables, so a complete (and more expensive) weather station is required to use these sophisticated methods. In addition to cost, the problem with these extensive data requirements is that conditions can vary greatly over short distances. Consequently, a single weather station provides estimates of water use that are applicable to only a small area. Simpler methods of estimating crop water use requiring only one or two weather variables are available, but they are less accurate and require local calibration.

Smith is testing the calculations made by different methods against data being collected in the field to find the most accurate and simplest method for computing consumptive use in mountain meadows. To collect field data, Smith and his team have installed nine lysimeters in representative irrigated meadows throughout the upper Gunnison River basin. The lysimeters look like large, square-sided buckets in which grass is growing. The water in the lysimeters is maintained at a level similar to that of the surrounding irrigated meadow by using a float valve attached to a supply reservoir. Water use is measured by changes in the level of water in the supply reservoir. Each of Smith's lysimeter sites also is equipped with a rain gauge and instruments for measuring weather variables.

One of the most popular methods of calculating consumptive use has been the Soil Conservation Service's (SCS) Blaney-Criddle method. The method has been a favorite because its only data requirement is average daily temperature, based on measurements of maximum and minimum daily temperatures. "In mountain meadows in the western United States, it is recognized that the SCS Blaney-Criddle method greatly underestimates water use unless crop coefficients are adjusted to meet local conditions," Smith says. However, even when these adjustments based on local methods are made, calculated values

of consumptive use and actual water use are poorly correlated. Using data collected in the mountain meadows, Smith tried to use alternative expressions of average daily temperature, such as the average of hourly temperatures throughout the day or just during the light period of each day, to calibrate the SCS Blaney-Criddle. The results of Smith's analysis indicate that water use is poorly correlated with average daily temperature regardless of the temperature expression used.

Smith and his co-workers were not completely surprised by these results. He notes that solar radiation is the best single weather variable that predicts consumptive water use. Fortunately, one lysimeter location was equipped with a complete weather station, so the group was able to conduct preliminary analyses to confirm the value of solar radiation as a predictor of crop water use. Radiation methods for estimating crop water use were investigated. One of these methods, called the Hargreaves method, which was developed in the 1970s but went relatively unnoticed until recently, looked promising because it was based on the use of temperature. But instead of using average daily temperature, this method relies on the difference between the maximum and minimum daily temperature.

"Looking back, the Hargreaves method should have been the first choice for these high-altitude environments," says Smith. "Days with radically different levels of solar radiation can have the same average temperature," Smith says. With one year of data collection remaining, Smith claims that the Hargreaves approach is producing much more accurate estimates of consumptive water use than the more conventional SCS Blaney-Criddle method.

Data requirements for the Hargreaves method are modest enough that Smith can imagine a day when the approach could be used over a wide range of conditions to monitor crop water use. The resulting data could then be used as a real-time inventory tool to aid Colorado officials in their efforts to monitor the state's compliance with interstate compacts.

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Forage Crops and Water Use

For the most part, environmental conditions determine the water use of plants, but different crops require different amounts of water even if they are grown under the same weather conditions. Forage crops, like hay, have low water requirements compared to most other crops. Forage crops are good crops for planting during drought or in naturally arid regions because they can be harvested at any growth stage. This means that the farmer can harvest forage crops early and escape drought-induced crop failures. Furthermore, established perennial forages will remain viable during drought periods only to re-initiate growth upon resumption of moisture from either rainfall or irrigation. Finally, seeding of annual forages is relatively inexpensive.

Forage crops have been grown in the dry, sunny Upper Gunnison River Basin since the 19th century, when farmers began using the mountain meadows to grow forage crops for draft animals. More recently, cattle have been raised in the mountain meadows. Mountain meadows supply the forage base for year-round livestock production in the Rocky Mountain region, and hay yields from mountain meadows average about 1.3 tons per acre.

Weed Warrior

CSU Scientist Investigates Biological Controls of Knapweeds

"Carefully investigated biological control can be an important tool in weed management."

Colorado State University

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Diffuse knapweed (Centaurea diffusa) and spotted knapweed (Centaurea maculosa) are exotic species that readily displace native vegetation, and now Ruth Hufbauer, assistant professor in the Department of Bioagricultural Sciences and Pest Management at Colorado State University, and her colleague Shanna Carney, assistant professor in the Department of Biology, are finding evidence that suggests these plants may be hybridizing.

Diffuse and spotted knapweed compete with other plants for sunlight, water, and nutrients and release chemicals from their roots that may act as herbicides on other plants (referred to as allelopathy). In addition, animals grazing aren't very interested in knapweed, which is a poor forage plant, but pollinators may be more attracted to knapweed than other flowering plants. Knapweed forces land managers to remove land from cattle production and institute expensive and indiscriminate herbicide spraying programs.

There are more than 80,000 acres of diffuse knapweed in Colorado and 3.5 million acres across the west. Spotted knapweed is less common in Colorado, with only 2,500 acres, but it may just be a matter of time until spotted knapweed gains more of a foothold in the state, as there are more than seven million acres of spotted knapweed across western North America. Knapweed has become so prevalent in certain areas that some residents can easily identify the plants. Diffuse knapweed has white flowers and spiny bracts. Spotted knapweed has purple flowers and spotted or black-tipped bracts. "But more and more, people have reported plants that sound like a hybrid of the two: plants with pink flowers, spots, and spines," Hufbauer says. These reports inspired Hufbauer to call in Carney, an expert on plant hybridization, to help investigate the source of the intermediate plants. With special funding provided to the Agricultural Experiment Station by the Colorado legislature for the express purpose of researching invasive plants, Hufbauer and Carney are investigating whether spotted and diffuse knapweed are hybridizing, and the researchers are trying to find the exact origin of the plants for the purpose of identifying possible biological controls.

Using DNA markers, the researchers are examining the levels of genetic variation in North American populations of spotted and diffuse knapweed. Hufbauer and Carney have discovered that many diffuse and spotted knapweed plants share the same chloroplast DNA sequence. "There may not be a lot of barriers between the spotted and diffuse knapweed hybridizing," Hufbauer explains.

Field and lab research supports Hufbauer and Carney's genetic research. Graduate student Robin Marrs recently found what seems to be a natural hybrid swarm. The population contained spotted knapweed, diffuse knapweed, and intermediate phenotypes spanning the spectrum between them that match descriptions of hybrids. The implications of this hybridization could be positive and negative. Hufbauer points to Jorge Vivanco's catechin research. Catechin is the "natural herbicide" released by the roots of spotted knapweed that inhibits the germination and growth of other plants. Diffuse knapweed secretes a distinct chemical, 8-hydroxyquinolone, which has similar effects. Catechin is toxic to diffuse knapweed, and 8-hydroxyquinolone is toxic to spotted knapweed. Hufbauer and her team were

concerned that the hybrid plants could be "superinvaders" that produce and detoxify both chemicals. However, when Marrs characterized the chemical exudates of the plants from her hybrid swarm, she found that the intermediate plants produced very little of either chemical. This could make the hybrids less competitive than the parent plants. "However, hybrids might be either more or less susceptible to specialized herbivores than the parent plants," Hufbauer says.

Now, Hufbauer hopes to identify a more exact origin for the weeds. Although it has been assumed that knapweed came over from Eurasia in the 19th century, probably in ship's ballast or straw, the exact origin of Colorado knapweeds are still unknown. European Centaurea samples are being sent to Hufbauer by René Sforza, a USDA employee working overseas. "It is particularly important to find where the weeds originated so that proper biological controls can be found and investigated. Insects or pathogens that might feed on the plant and arrest its growth in its native land might work to control the Centaurea populations in Colorado better than the current biological control options," Hufbauer says. "However, these controls need to be thoroughly investigated before they are applied. Once a biological control is put out in an environment, it can't be taken back. However, it can introduce a host of other problems."

It is this painstaking process of making sure that a decision is right not just for the next three years but for the next 50 years or more that attracted Hufbauer to studying biological control. Hufbauer is optimistic that carefully investigated biological control can be an important tool in weed management.

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More About Diffuse and Spotted Knapweeds

Diffuse knapweed is a biennial. In the plant's first year of growth, it only produces a rosette of foliage, but in its second year of growth, it produces a seed stalk. Diffuse knapweed spreads its seed by falling over when mature and tumbling in the wind across the land.

Although spotted knapweed infestations are not as severe in Colorado as diffuse knapweed, spotted knapweed has the potential of spreading over large areas in a short period of time. Each plant produces up to 25,000 seeds that are dispersed by wind, animals, and people, and seeds may remain viable for eight years. Spotted knapweed tolerates dry conditions, similar to diffuse knapweed, but will survive in higher moisture areas as well.

Knapweeds are poisonous to horses, causing chewing disease for which there is no cure.

The Sweet Taste of Success

Colorado State Researcher Meets the Challenge of a Sweet Corn Pest

Colorado super-sweet corn has developed a national reputation for quality.

Sweet corn is an important component of the agricultural economy of western Colorado. Sweet corn acreage has grown consistently since 1990, and local marketing companies negotiated national distribution contracts in 2001. Sweet corn is sold under a Market Order, which has strict quality guidelines, and corn from each field is inspected before shipment is allowed. Dusky sap beetle, *Carpophilus lugubris*, is a pest that attacks and contaminates corn ears. If infestation levels exceed those specified by the Market Order, the field is rejected and the grower faces a financial loss. If sweet corn shipments have consistent contamination that falls within the Market Order specifications but is detectable by grocers and consumers, extension of national marketing contracts is jeopardized. This is what occurred in 2001.

In crops where quality is not of such concern, the black, quarter-inch-long dusky sap beetle often is ignored, but Colorado super-sweet corn, particularly Olathe-grown sweet corn, has developed a national reputation for quality. The 2001 sap beetle infestation resulted in almost 10 percent of the sweet corn crop being rejected and a loss of more than $500,000 to growers. The future of the specialty crop was in jeopardy. An emergency plan for dealing with the beetle was required. Bob Hammon, who was working as a research scientist at the Agricultural Experiment Station Western Colorado Research Center and who now works as an area extension agent with Tri-River Cooperative Extension, was called in to develop a strategy for dealing with the pest.

Traditionally, growers have concentrated their pest management efforts on the corn earworm. Corn that is shipped nationwide often is sprayed with insecticide several times throughout the season to control corn earworm. "At the end of the season, growers were just bumping up their schedule to twice a week in order to deal with the dusky sap beetle," Hammon recalls. There was no research to justify the scheduling decision. Hammon decided that it was time to investigate the biology of the dusky sap beetle for clues as to how the pest might be managed.

With funds from the Agricultural Experiment Station and the Colorado Specialty Crop Program, Hammon began his research. A six-acre field of sweet corn was purchased for studying the dusky sap beetle's biology and for trying different sprays and schedules. Hammon caged beetles on ears of corn to examine their lifecycle. He discovered that the adult beetles were in the field from the moment the corn pollen started falling but that the adults did not enter the ears until about seven days before harvest. The beetles were attracted to the fermentation process that was going on as the corn was producing its sugars. After entering the ear through the freshly grown silk, the adults would take about three days to produce their pale, worm-like larvae. With this finding, Hammon was able to revolutionize the spray schedule for the pest, concentrating the sprays into the final few days before harvest. Hammon credits Leonard Felix, owner of the Olathe Spray Service, with putting the new spray schedule into an affordable system and testing it on commercial fields. "Once the spray schedule change was made, there were no more rejected acres, and sap beetle infestations in treated fields

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dropped to the lowest levels experienced in years," Hammon says.

Hammon notes that his spray schedule does not necessarily reduce the amount of pesticide used on corn but ensures that the sprays are effective. Despite the fact that sweet corn is sprayed a number of times throughout the growing season, Hammon points out that pesticide residues are undetectable on corn kernels. "The husk is very effective at protecting the corn from exposure to pesticide," Hammon says. However, Hammon is interested in finding ways to reduce the use of pesticides on sweet corn by means of pheromone traps using fermenting attractants like bread dough or rotten fruit. These methods might be particularly applicable to the fresh market sweet corn industry, where corn is handpicked several times over a series of days.

This year, growers have enthusiastically accepted Hammon's pest management program, and Hammon is continuing his study of the dusky sap beetle. In addition to pheromone trapping, he is investigating how post-harvest management might impact the huge flights of the beetles that typically occur in October. "Time will tell," Hammon says about his pest management efforts.

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A Growing Concern: Colorado Sweet Corn

Before Colorado sweet corn became a nationally recognized quality crop, Olathe, Colorado, was just another struggling small town. In the late 1970s, area farmers were having a hard time making ends meet. There wasn't much of a market for sugar beets and barley, the crops traditionally grown in the area. Then, Olathe farmers started cultivating new varieties of sweet corn, and the town's economic situation turned around. Every year in August, the townspeople of Olathe now celebrate their winning crop with a Corn Festival that attracts nearly 20,000 participants.

The cultivation of corn in Colorado can be traced back to the ancient Anasazi, who farmed at nearby Mesa Verde. Olathe sweet corn is a descendant of that staple food. Sweet corn is low in fat, sodium-free, and a good source of fiber and vitamin C.

Potato Pathologist

Colorado State University Research Protects Colorado Seed Potatoes

"Researchers are making sure that Colorado seed potatoes maintain their excellent reputation."

In the 1840s, a tragic event in the history of agriculture changed a country forever. A fungus destroyed the Irish potato crop, the population's major food source, and precipitated the Irish Potato Famine. Rob Davidson, Colorado State University Cooperative Extension state seed potato specialist and the potato pathologist for the Colorado Potato Certification Service, is intent on not repeating history.

Although potatoes are not the primary food of the United States, Colorado potatoes are big business. Colorado routinely ranks among the top five or six states in acreage planted, and Colorado is the fourth largest producer of potato seed. Growers in the state produce in excess of 150 cultivars and sell 1.4 million hundredweight of seed throughout the United States and to several international markets. The majority of Colorado's seed potatoes are produced in the San Luis Valley.

Davidson and other researchers at the San Luis Valley Research Center's Colorado Potato Certification Service are involved in making sure that Colorado seed potatoes maintain their excellent reputation so that growers can continue to expand their markets and their profits. "Certification," Davidson explains, "is the official process of evaluating potatoes based upon a set of standards relating to seed history and acceptability for production. The certification process focuses on disease tolerances, specified growing and production regulations, pathogen/disease testing, grade inspections, and grower expectations, and ends with issuance of an official state tag indicating the status of the seed within the program. A seed lot is classified according to years of production, levels of disease, handling methods, and other criteria. The seed lot may be classified as entered, downgraded in class, or rejected as seed. In a practical sense, this means that the seed has gone through a series of inspections and met certain conditions that give assurance to the buyer that the seed should produce a reasonable crop with a minimum of problems during the first season of growth."

In addition, Davidson and his co-workers have been responsible for helping to identify the various disease and pest threats to successful certified seed potato production in Colorado and other parts of the west and for developing management strategies to help growers limit or control pest and disease problems. Their work has been instrumental in reducing the impacts from diseases such as bacterial ring rot and blackleg/soft rot to negligible levels. When other seed regions have been struggling, Davidson's research, along with the research of his colleagues like Richard Zink, has helped Colorado growers continue to produce high-quality seed stocks for sale into the surrounding region. For example, Davidson has conducted research on a technique for killing potato vines at the end of the growing season. "Growers use a variety of techniques," he says, "to kill vines at the end of the season in order to prevent additional spread of virus diseases and provide for higher-quality potatoes with good skin set. Research, funded in part by the Agricultural Experiment Station, demonstrated that vines could be chopped and sulfuric acid (one type of vine desiccant) could be applied within 48 hours with no spread of bacterial or virus diseases. This is important because many of the cultivars being grown have very large vines that are difficult to kill with only one application of acid. This research allowed the growers to chop the vines mechanically

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(a practice that normally would spread many different types of viral or bacterial diseases) to reduce foliage, apply sulfuric acid once, and have an effective, safe, and economical vine kill."

Another key focus of this research program over the past several years is the evaluation of advanced clones from the Colorado cultivar development program, headed by David Holm. Clones are screened for their reaction to several of the major disease threats found in Colorado including bacterial ring rot, potato virus Y, and potato leafroll virus. Through this screening, clones that have problems expressing disease symptoms are removed from the system. This has resulted in significant reductions of these particular diseases being found in the certified seed crop. Currently, Colorado producers raise around 7,900 acres of Colorado-developed cultivars, representing more than 50 percent of the seed acreage entered into the program. "Since many of these clones are under Federal Plant Variety Protection, additional revenues to support research are generated for CSU through the collection of royalties. This results in a win-win situation for both the growers and the University," Davidson says.

Davidson's potato research seems never-ending. Presently, he is particularly concerned about two serious threats to Colorado seed potato production – importing serious diseases and pests from other regions and the practice of growers cultivating noncertified or common seed in the seed-producing region and perpetuating disease problems or reintroducing disease problems into otherwise clean, certified seed.

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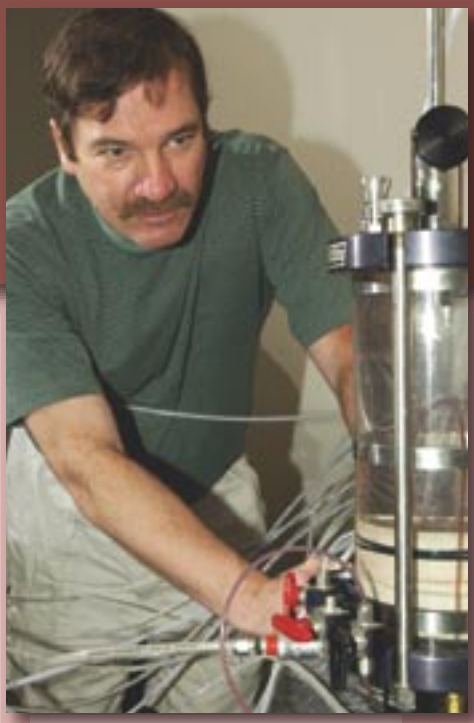
A Brief History of Potatoes in the San Luis Valley

The San Luis Valley produces 92 percent of Colorado's potatoes. The valley's warm, sunny, summer days and cool nights are perfect for growing potatoes, while the cold, dry winters help reduce pest and disease problems in the region.

The San Luis Valley is one of the oldest potato-growing areas in the country. Farmers began growing potatoes in the valley around 1875. Today, the two major types of potatoes grown in the San Luis Valley are the russets and the reds. The russet is a familiar oval-shaped, russet brown, smooth-textured potato. The most popular red potato in the region is a variety known as the Sangre, which was developed in the San Luis Valley as an all-around potato, suitable for a variety of uses. The valley also is known for its Yukon Gold potatoes, which have sweet yellow skin and buttery flavor; the Chipeta potato developed especially for potato chips; and blue potatoes.



Helping to Protect Groundwater

Charles Shackelford, professor of civil engineering at Colorado State University and director of the Rocky Mountain Regional Hazardous Substance Research Center, is concerned about nitrate and other dangerous substances seeping into groundwater from animal feedlots. Shackelford, along with civil engineering assistant professor Kenneth Carlson, is investigating whether manufactured geosynthetic clay liners (GCLs) are a better way of lining animal waste lagoons than traditional compacted clay liners.

Lagoons typically contain animal waste for periods ranging from 6 to 24 months. They allow waste to partially decompose before it is applied to fields. At present, most animal waste lagoons are lined with compacted clay. A pit is excavated for the lagoon, and either natural clay near the pit is recovered and re-compacted to line the pit, or if natural clay is not available locally, a suitable alternative clay is shipped to the site to line the pit. "This approach leads to a great deal of inconsistency in clay liners from region to region because of the natural variability in the available clays," Shackelford says.

In contrast, GCLs are manufactured, which results in more uniform properties. As a result, the use of GCLs has the potential for establishing more uniform standards for lining animal waste lagoons throughout the country. GCLs have been manufactured since about 1990, but only recently have they been marketed for use in lining animal waste lagoons. GCLs consist of a thin layer of naturally occurring, high-swelling clay called sodium bentonite, sandwiched between two textile-like materials, referred to as geotextiles. The GCL typically is held together with glue or by stitching or needle punching through the geotextiles. The product is shipped in rolls and simply is rolled out to line the excavated pit. When the product is shipped, it is only about 5-6 mm thick, but when water is added, the bentonite swells, resulting in thicknesses typically of 10-15 mm.

Unfortunately, bentonite also can contract significantly when exposed to certain chemicals and chemical concentrations, resulting in increased leakage. Therefore, Shackelford and his research team, using funding from the Agricultural Experiment Station, are testing the product's stability against contraction using a simulated animal waste stream containing 147 mg/L of calcium, 679 mg/L of sodium, 1756 mg/L of chloride, and 415 mg/L of ammonium-nitrogen. The composition of the waste stream is based on literature characterization of a wide variety of actual animal waste streams. Clint Brown, a graduate student working with Shackelford, is permeating a GCL using the simulated waste stream as well as tap water processed to remove ions under both aerobic and anaerobic conditions to evaluate the effects of the simulated waste stream. The results of these tests indicate that the simulated solution had little impact on the hydraulic conductivity of the GCL. The GCL was able to maintain a low hydraulic conductivity throughout the tests, and the hydraulic performance of the GCL essentially was unaffected by whether the tests were conducted under aerobic or anaerobic conditions. Although the simulated animal waste stream apparently does not have a high enough chemical strength to pose a threat to the stability of GCLs, Shackelford warns that more research needs to be done on

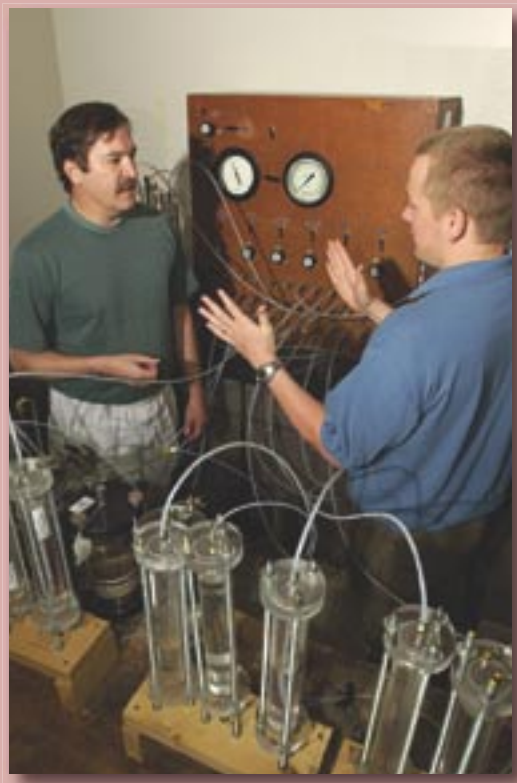
"The natural variability in clays leads to inconsistency in traditional compacted clay liners."

Colorado State University

Knowledge to Go Places

using GCLs to store other types of wastes, including actual animal waste streams.

Now Shackelford is conducting tests to determine the potential for adsorption of chemical constituents to the bentonite and geotextile of GCLs. The results of these tests will provide a partial assessment of the ability of the GCL to delay the migration of the waste stream constituents. At the same time, Carlson, Shackelford's co-investigator, is analyzing waste samples from lagoons, groundwater, and surface water around Colorado to detect the presence and concentration of three categories of antibiotics widely used in animals across the United States.



GCLs are becoming increasingly popular in the feedlot industry because they are economical and easy to repair. Ultimately, Shackelford hopes to determine whether GCLs can be used as a safer alternative to current lining systems in animal waste containment lagoons. He hopes that his research will be instrumental in developing a set of design guidelines pertaining to the use of GCLs in animal waste disposal practice.

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The Many Uses of Bentonite

Since being discovered in 1890 near Fort Benton, Wyoming, the clay known as bentonite has been quarried for a variety of uses. Bentonite's volume increases several times when it comes into contact with water, making it valuable for a wide range of applications.

In addition to its use in GCLs, bentonite is used in industry to create molds for casting iron and steel and as a mud constituent for oil and water well drilling. Bentonite is also crucial to paper making, where it improves the efficiency of conversion of pulp into paper as well as the quality of the paper. In paper recycling, bentonite offers useful de-inking properties.

At home, bentonite can be found in the medicine chest in pharmaceuticals like calamine lotion, wet compresses, and anti-irritants used for eczema. Mud packs, baby powders, and face creams may also contain bentonite. In the kitchen, bentonite is an ingredient crucial to the processing of edible oils and fats (soya, palm, canola oil). It also is used as a clarification agent in drinks like beer, wine, and mineral water and in products like sugar or honey. Bentonite is an essential ingredient in laundry detergents and liquid hand soaps where it removes the impurities of solvents and softens fabrics.

However, cat owners may most readily recognize bentonite. Due to bentonite's ability to absorb refuse by forming clumps, the clay is a common ingredient in cat litters.

Eat More Fish

The Impact of Omega-3 Fatty Acids on Osteoarthritis

"To me, the big issue is whether we should have more fish oil in our diets."

Colorado State University

Knowledge to Go Places

The health benefits of the essential omega-3 fatty acids found naturally in fish and a few other foods are in the news. Associate professor Mary Harris and Rod Hansen of the Department of Food Science and Human Nutrition are investigating how these omega-3 fatty acids might slow down the action and production of matrix metalloproteinaises (MMPs), a family of enzymes that are influential in causing osteoarthritis.

MMPs are normal enzymes associated with growth and the turnover of tissue. They break down tissue so that new tissue can grow. However, when there are too many MMPs, osteoarthritis can result.

An estimated 20.7 million Americans suffer from osteoarthritis. It is a chronic, progressive, and debilitating disease characterized by the breakdown of the joint's cartilage. Cartilage breakdown causes bones to rub against each other, resulting in pain and loss of movement. The degenerative disease affects the hands and weight-bearing joints of mostly middle-aged and older people. The Arthritis Foundation reports that knee osteoarthritis can be as disabling as any cardiovascular disease except stroke.

Harris and Hansen speculated that supplementing a diet with omega-3, or fish oil, might help slow the course of this disease. As osteoarthritis is not unique to the human population, Harris and Hansen conducted their research at the Colorado State University Veterinary Teaching Hospital on companion dogs that had torn cruciate ligaments needing a surgery called tibial plateau leveling osteotomy (TPLO). "When a dog comes into the Department of Clinical Sciences and Small Animal Orthopedics needing TPLO on one knee, its other knee is almost always bad as well, but the other knee has not yet become acutely affected," Hansen explains. "The dogs with a bilateral chronic degenerative joint disease allow us to investigate how a diet containing fish oil might affect osteoarthritis in both its acute and chronic phases," Harris says.

With a grant from the Colorado State University Agriculture Experiment Station and a separate grant from Purina, Harris and Hansen along with colleagues Ken Allen and Elizabeth Pluhar compared the health of dogs that were fed an omega-3 enriched Purina food with dogs in a control group that were fed a similar Purina product with no omega-3. The dogs were fed the special diets from 7 days prior to the surgery to 56 days post-surgery. "The dogs seemed to enjoy the food and had no trouble digesting it," Hansen says. Blood and synovial fluid samples from the acute and chronic knees were taken on six different days during the recovery period. The researchers discovered that MMPs in the acute knee were not influenced by the omega-3 diet. "We think the surgery overwhelmed whatever nutritional intervention could accomplish," Hansen says.

However, the MMPs in the chronic knee were regulated by fish oil. MMPs can be regulated in at least three different ways: the production of MMPs can be slowed, MMPs can be prevented from being activated, and

the body's disposal rate of MMPs can be increased. In Harris and Hansen's research the omega-3 diet seemed to affect all three control points of MMPs. Omega-3 slowed down the production and prevented the activation of MMPs and also helped increase the body's disposal rate of MMPs.

"To me, the big issue is whether we should have more fish oil in our diets," Hansen says. "In dogs, there were positive results after 63 days of treatment – a very small portion of a lifetime. If we ate more fish oil throughout our lives, would the results be more dramatic?"

Certainly treating osteoarthritis with fish oil seems preferable to traditional treatments. Osteoarthritis usually is treated with aspirin and other anti-inflammatory drugs. These drugs act the same as fish oil but can be costly and have serious side effects like tendonitis, steroid-induced osteoporosis, gastrointestinal bleeding, and liver and kidney disease.

In the future, Harris and Hansen will continue to investigate the health benefits of omega-3 fatty acids. Harris is enthusiastic about beginning a new project funded by the Agricultural Experiment Station in which she will study MMPs in a clinical population, following the progress of pregnant women as they intake fatty acids to reduce pre-term delivery. Hansen plans on looking at omega-3 and possibly other fatty acids in connection with other diseases such as gum disease and cancer.

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The Health Benefits of Omega-3

Omega-3 fatty acids are essential to human health. Promising research is being conducted on the beneficial effects of omega-3 on health problems ranging from psoriasis to cancer. In the womb, the omega-3 fatty acids play an important role in fetal brain and vision development, and they continue to play a major part in our health at every stage in life by assisting in the prevention and management of certain diseases and chronic conditions.

Oil-rich fish and supplements such as fish oil and cod liver oil are the richest and most readily available dietary sources of omega-3. Omega-3 fortified everyday foods like bread and fruit juices are in production in the United States.

Better Beef

Assessing the Economic Impacts of Improved Beef Cutability and Palatability

"It is research like this that has the potential to help farmers and ranchers improve their income."

Colorado State University

Knowledge to Go Places

Cattle and calves in the United States were valued at $2.6 billion in 2001, and the beef industry is the largest component of Colorado agriculture. But Stephen Koontz, associate professor of agricultural and resource economics at Colorado State University, wants to make the industry better, not simply bigger. "Many agricultural experiments are aimed at producing more of a product, which ultimately lowers prices," Koontz explains. "My research is intended to improve a product in order to enhance demand."

Koontz's research was inspired by the declining demand for beef that has occurred over the last 30 years. This trend is due to a number of factors, but a significant part of the decline can be attributed to palatability problems. Tenderness is probably the most important quality that contributes to palatability of beef, and Koontz claims that consumers rate between one-out-of-four and one-out-of-five beef eating experiences as unsatisfactory.

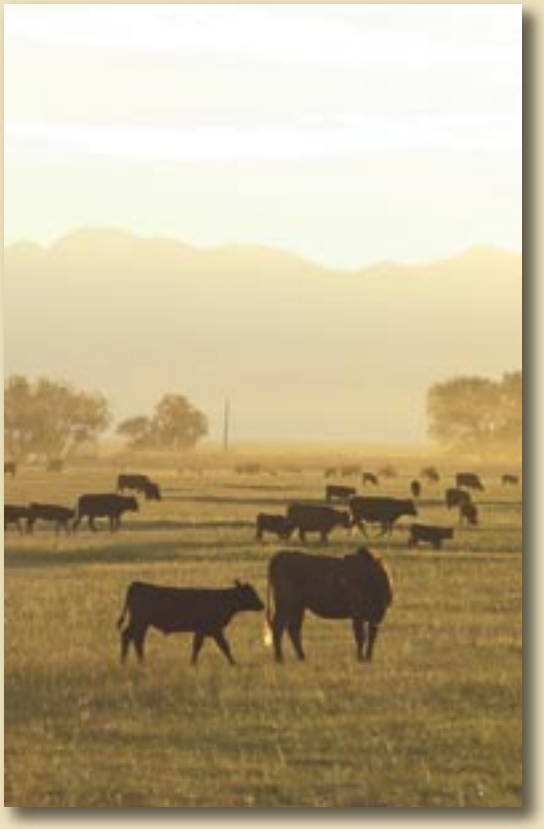
Koontz and his colleague R. Mark Enns, who is an assistant professor of animal science and a geneticist, are using funds from the Agriculture Experiment Station along with checkoff dollars from the National Cattleman's Beef Association to measure the benefits and costs of developing tenderness EPDs (Expected Progeny Differences) for beef cattle breeds and to assess the economic benefits of making beef more palatable.

EPDs are how seedstock producers improve different characteristics of beef animals. For example, there have long been EPDs on animal weight and growth performance. As a result, producers are able to look across the pool of breeding stock and select animals that will produce offspring that are larger and will grow faster. In a national project to investigate EPDs, Colorado State University worked with Kansas State University, Texas A&M University, Cornell University, and the USDA Agricultural Research Service Meat Animal Research Center. Partial funding for the project was provided by the National Cattlemen's Beef Association and the participating beef cattle breed associations. The research conducted on EPDs allows producers to select carcass characteristics, including tenderness. This EPD research also fits well with other research conducted at Colorado State. Specifically, the BeefCam Tenderness Evaluation System, a video-imaging technology developed by Keith Belk and Gary Smith, allows producers to get a picture of carcass tenderness and use that information to adjust their management practices.

What makes for a quality piece of beef? Koontz says tender beef is a result of good genetics, good management, good harvest and fabrication, slight aging, and knowledgeable preparation.

Would consumers be willing to pay more for a more tender product? Koontz was unwilling to rely on consumer surveys to answer this question. "Surveys are somewhat unreliable; people may not do exactly what they say they will do when it comes to spending their own money." Instead, Koontz and former Colorado State graduate student Megan Bruch looked at grocery store data – specifically the National Beef Tenderness Survey conducted by the National Cattleman's Beef Association – to discover how much more consumers will pay for a more tender product. Through the data, they determined that more tender cuts are priced at a premium.

Koontz found that a 10 percent improvement in tenderness would result in a 3.5 to 4 percent increase in retail beef prices. If the resulting product improvements would cause consumers to bring new money to the beef industry, the potential benefit to the industry could be huge. The short-term cost of improving beef palatability would be more than offset by permanent increased industry revenue.



Citing the fact that producers have not yet set up a system for making sure that high-quality producers get paid more and tough beef gets discounted, Koontz claims, "There needs to be a way to track beef tenderness through the marketing system and across different producers. There need to be changes in the beef pricing, marketing, and grading system." Koontz says, "In the short-term, it likely will be niche and high-end marketers who adopt this new technology and develop a system to make it work. Then if changes can be made in the industry grading system, the technology has the potential to be very successful across the industry as a whole."

"It is research like this that has the potential to help farmers and ranchers improve their income," Koontz says of his findings. "Declining beef demand has hurt this industry." Koontz feels that the findings and technology offered by the Colorado State University research stands to improve the end product and increase demand.

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CSU Develops a New Tool for Evaluating Beef

Colorado State University researcher, Keith Belk and his colleagues have created a revolutionary tool called BeefCam®, which helps the beef industry attract new customers and be more profitable. Based on color vision technologies, BeefCam® is becoming the technological foundation for improving beef grading and marketing around the world.

BeefCam® is a video-imaging technology that scans beef carcasses into color-differentiated images from which the subsequent eating quality can be determined with a high degree of predictability. For instance, BeefCam® can measure lean color as it relates to the pH of the lean tissue, which can be an indicator of beef tenderness. BeefCam® helps beef processors channel the most palatable carcasses toward value-added marketing programs. The result is a higher-quality, more consistent product that keeps customers coming back for more.

BeefCam® research began with Colorado State University and Hunter Labs of Virginia in 1997. SmartMV, a Hunter Labs subsidiary and Research Management Systems (RMS) worked with Colorado State University to commercialize the system. BeefCam® was incorporated into the RMS Computer Vision System (CVS) technology. The commercial BeefCam® System, first operational May 2000, continues to operate for the Nolan Ryan Tender Aged Beef program.

Colorado Agricultural Experiment Station Funding for Fiscal Year 2003-2004

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 from 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.

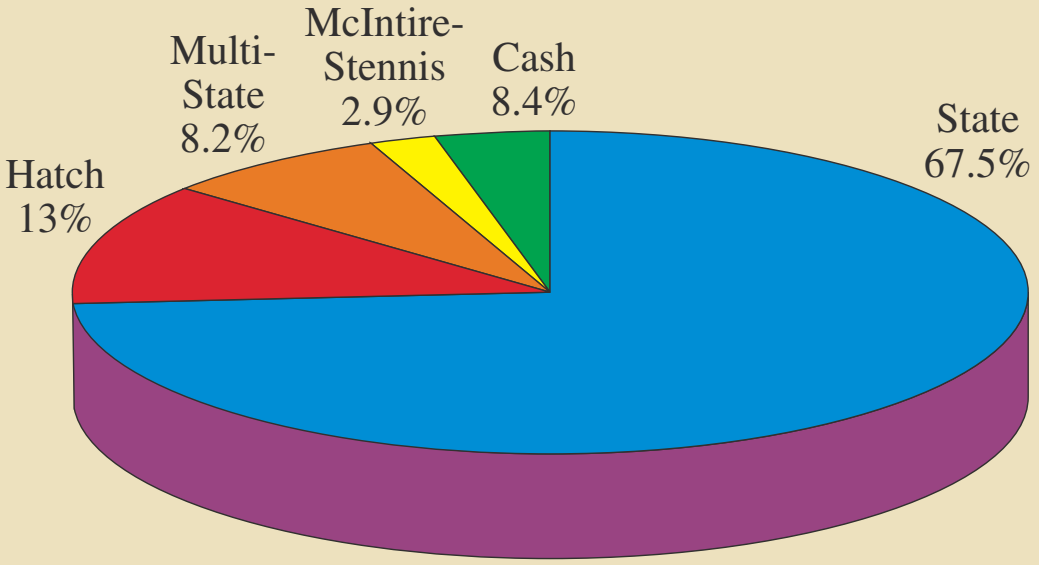
• Hatch – Funds appropriated by the federal government to each land-grant university for support of a base research program in agriculture and natural resources. These funds were authorized by the Hatch Act of 1887, as amended by the Agricultural Research, Education, and Extension Reform Act of 1998 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 and number of farms.

• 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 2002-2003 fiscal year, contract and grant funding from these external sources contributed in excess of $20 million of support to our research programs.



Total Budget: $11,587,036

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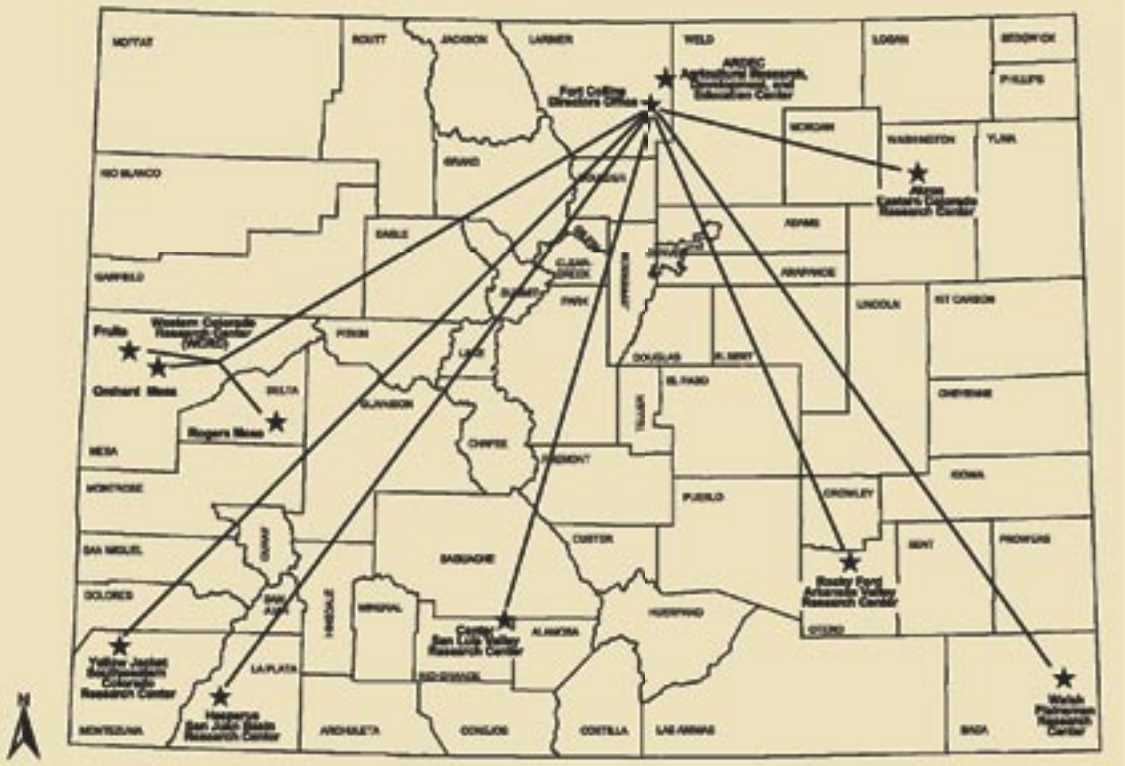
Colorado Agricultural Research System



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The Colorado Agricultural Experiment Station 2003 Annual Report was produced by the Colorado Agricultural Experiment Station, Colorado State University Outreach Communications and Technology, and Colorado State University Publications and Printing.

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