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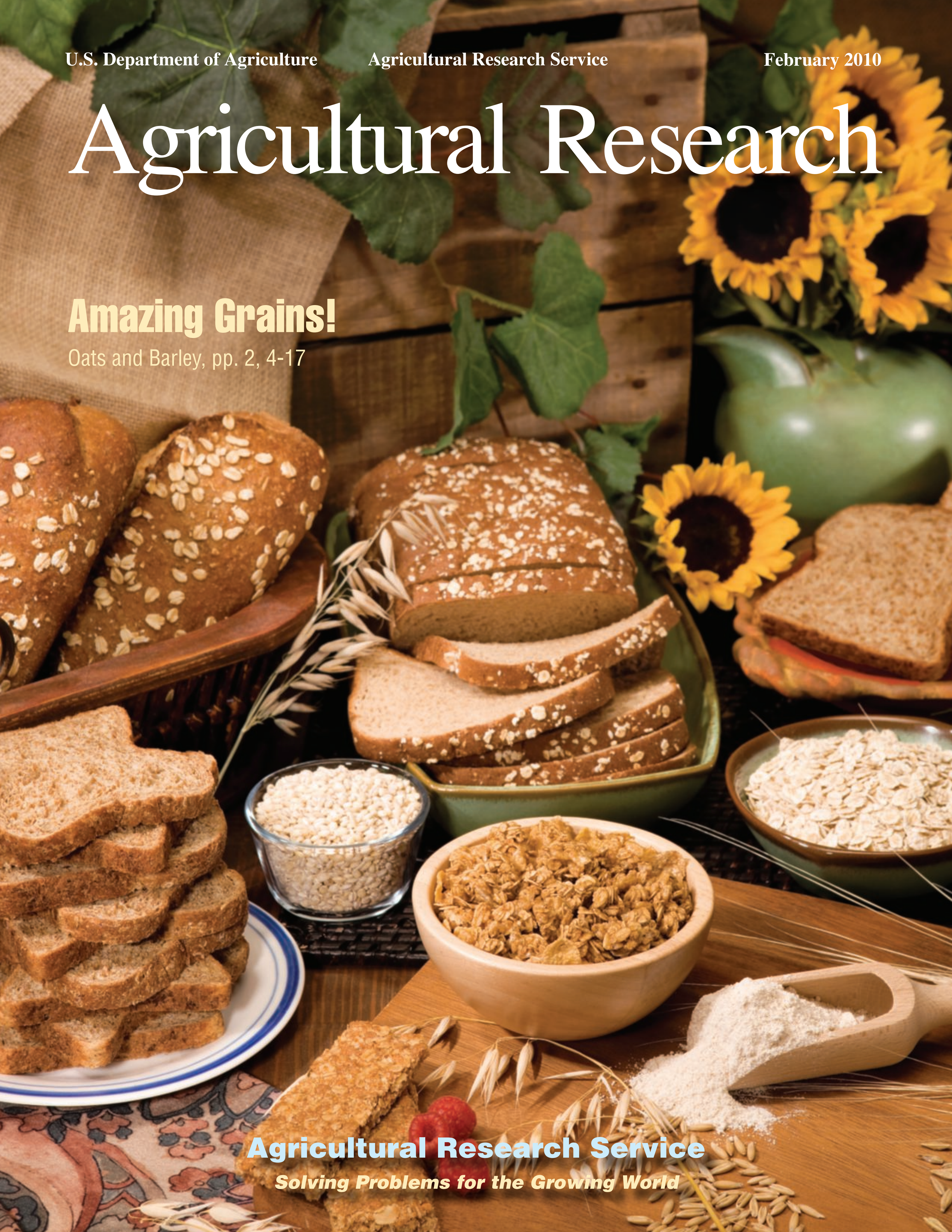
Agricultural Research



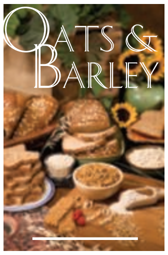
Amazing Grains!

Oats and Barley, pp. 2, 4-17

Agricultural Research Service

Solving Problems for the Growing World

ARS Research Partnerships Are Critical to U.S. Grain Production



Those “amber waves of grain” across America’s farmlands are contributed to in part by public- and private-sector researchers working together. The Agricultural Research Service’s oat and barley research helps farmers, food producers, and consumers reap production, quality, and nutritional benefits. The research community for U.S. oat and barley production is relatively small but is strengthened by remarkable coordination and cooperation. ARS’s role is pivotal. Cooperative projects—including ARS and university researchers, with support from USDA and other federal agencies, and private industry—are enabling researchers to leverage resources and successfully work together for oat and barley improvement.

Major diseases, like cereal rusts in barley and oats and *Fusarium* head blight (scab) in barley, threaten growers and major U.S. industry sectors that thrive on these two crops. U.S. oat producers are concerned that supplies will be lost unless we protect the crop from new diseases. Oats are used in breakfast cereals, snack foods, flour, and baked goods and as animal feed. Last year, nearly 88 million bushels of oats were produced in the United States alone, valued at about $262 million.

Barley production was valued at $1.2 billion, with more than 239 million bushels produced in the United States. Barley is used in foods and malt (for brewing beer) and for animal feed. The economic benefit generated from this crop is vast. The malt industry alone generates 1.7 million jobs. Even a moderate disease outbreak in these crops can significantly reduce yields, which in turn can hurt the U.S. economy. The impact on global cereal production is even more severe, since these and other grains are staples in other countries.

ARS is leading oat and barley research partnerships, made possible by federal and private-sector funding. A major example is the ARS-managed U.S. Wheat and Barley Scab Initiative, which involves more than 70 scientists from universities, ARS, and other organizations coming together with farmers, millers, and processors to fight *Fusarium* head blight—an economically devastating crop disease. (See story beginning on page 4.)

Other cooperative oat and barley projects are made possible through funding from USDA’s Agriculture and Food Research Initiative (AFRI) and the National Science Foundation (NSF). AFRI and ARS fund high-priority agriculture issues, such as breeding tools and molecular markers in oats and barley, while NSF provides grants for fundamental research relating to oat and barley improvement. Industries and associations, which include growers, millers, and processors, are also providing support for research on these crops.

These efforts are enabling oat and barley researchers to exploit new genomic strategies, develop new molecular markers, and work together for oat and barley improvements nationwide. The result is that researchers are now making good progress in developing new varieties with disease protection and improved nutritional quality—and even some with bioenergy traits.

ARS researchers are also collaborating with scientific organizations across the globe to respond to disease threats (see story on page 8). This international cooperation is bringing together advanced scientific knowledge in genomics, genetics, and breeding to help researchers identify effective genes from domestic and wild oat and barley lines that impart resistance to oat and barley diseases.

Beta-glucan is a soluble fiber that helps lower blood cholesterol levels and has been associated with maintaining healthy heart function. The *Dietary Guidelines for Americans* recommends eating more than three servings of whole-grain products a day. In addition, the U.S. Food and Drug Administration recently issued a regulation allowing companies to use a food-label health claim that associates soluble fiber from certain foods, like oats and barley, with reducing heart disease risks. ARS researchers have identified markers in the oat genome that can help them identify oat varieties high in beta-glucan. Other ARS scientists are developing all-oat and all-barley breads high in antioxidants, fiber, and vitamins—which may help Americans meet federal nutrition guidelines (see page 16). Scientists at ARS’s human nutrition research centers continue to evaluate the role of oats in a healthy diet. ARS’s role in this critical arena will ultimately help expand the market for these crops.

ARS researchers are also investigating winter barley’s use as a biofuel (see page 14). These projects are part of a USDA bioenergy strategy focused on providing alternative petroleum fuel sources to Americans. The future emphasis will be on using and improving barley grain as an economically feasible bioenergy crop—offering U.S. farmers one more option for generating income from this crop.

Oats and barley play leading roles in our nation’s food and feed production systems. Thanks to strongly coordinated partnerships, these two crops—and the industries built around them—will continue to thrive.

Kay Simmons
Acting Deputy Administrator
Crop Production and Protection
Beltsville, Maryland

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Agricultural Research

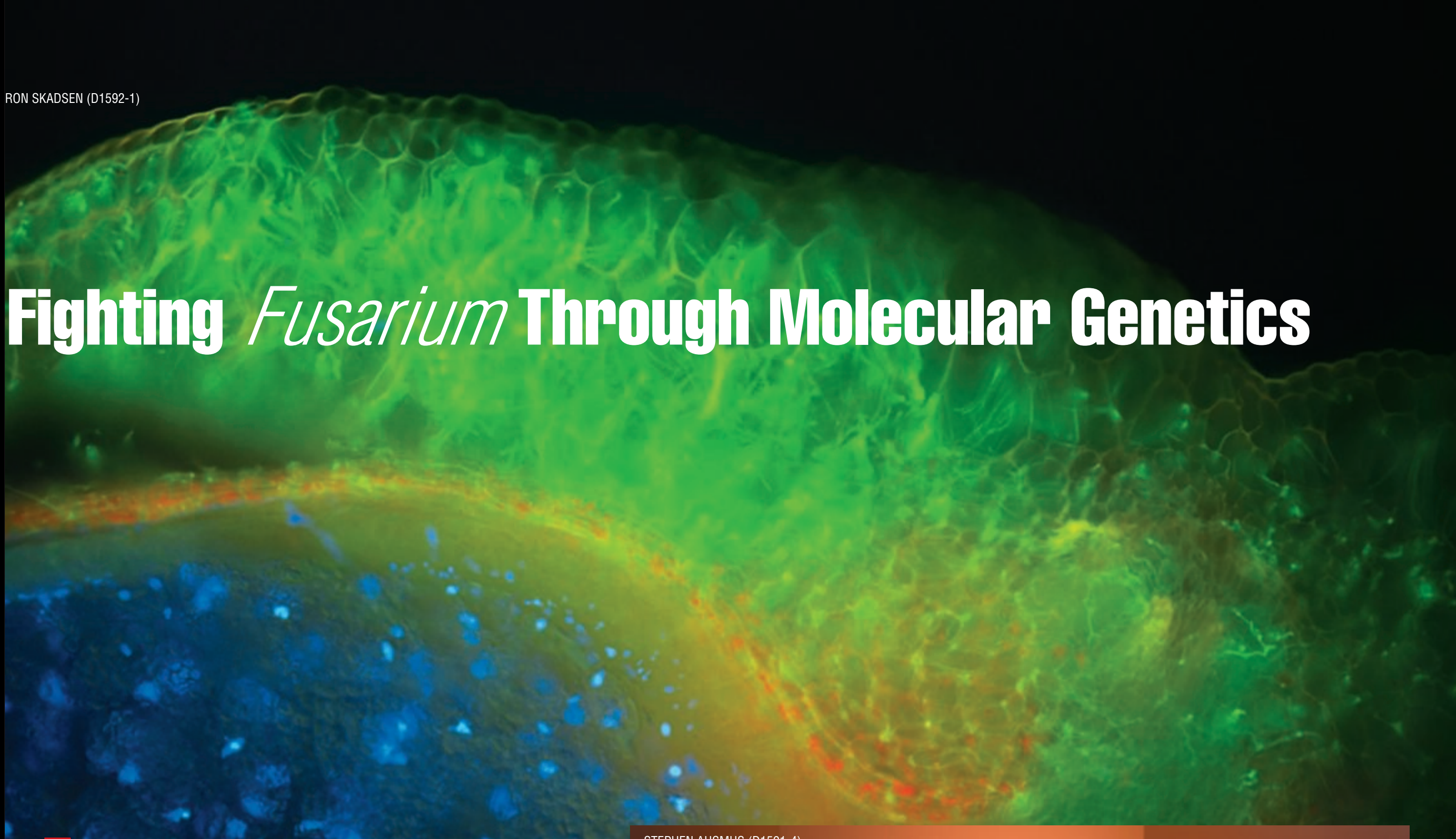
Solving Problems for the Growing World

Cover: ARS scientists are helping farmers, food producers, and consumers reap production and nutritional benefits through oat and barley research. Some of the many foods we derive from oats and barley are breads, health bars, pearled barley, barley and oat flakes, hot and cold cereals, and oat and barley flour. Photo by Peggy Greb. (D1662-2)

IN THE NEXT ISSUE

CHILDHOOD OBESITY—Take a look at an old school yearbook, maybe yours or your parent's. Then look at one from the past few years. You will likely see more overweight kids in the recent one. The next issue of the magazine looks at some of ARS's research on possible reasons for this and what we can all do to help prevent it.

RON SKADSEN (D1592-1)

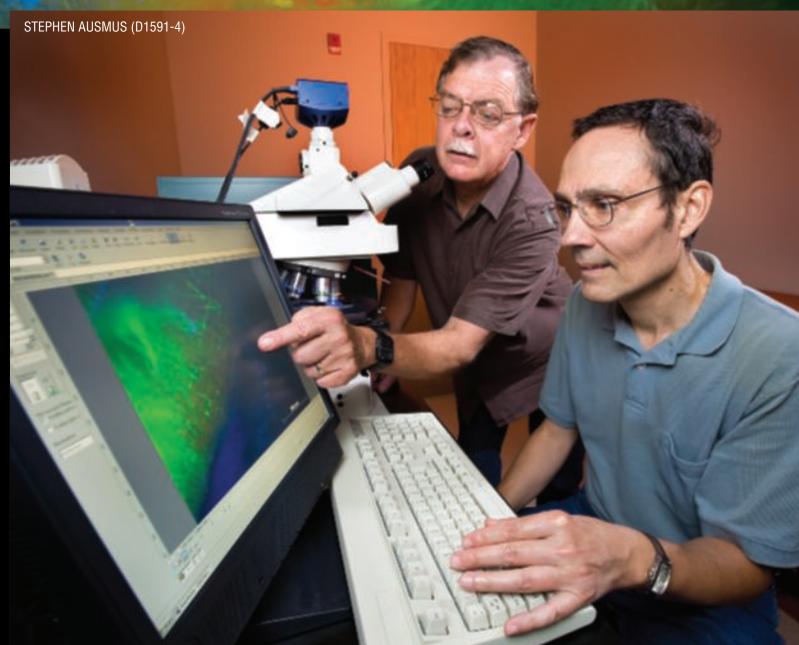


Fighting *Fusarium* Through Molecular Genetics

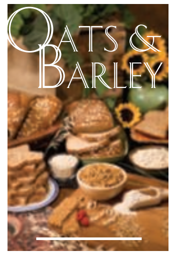
In Madison, Wisconsin, as part of the U.S. Wheat and Barley Scab Initiative (USWBSI), ARS plant molecular biologist Ron Skadsen is working to understand and improve barley's resistance to the fungal pathogen *Fusarium graminearum,* which causes the devastating disease commonly known as "scab." Scab reduces yield by causing sterility and shrunken kernels and contaminating the grain with mycotoxins.

Skadsen, who is in the Cereal Crops Research Unit, first sought to identify the barley tissues that *Fusarium* most readily attacks. He infected barley seed spikes with *Fusarium* transformed to contain a green fluorescent protein that makes the fungus glow neon green when examined under a fluorescence microscope. Skadsen found that *Fusarium* attacks the protruding seed tip of the developing seed, the soft tissue connected with it (just under the hull), and, to a lesser extent, the seed's outer hull.

STEPHEN AUSMUS (D1591-4)



Molecular biologist Ron Skadsen (left) and technician John Herbst use a fluorescence microscope to view a thin cross section of a barley seed. The larger image, at the top of the page, shows that the seed's epicarp tissue layer is infected with *Fusarium graminearum* (seen as fluorescent green). The fungus stops at the testa layer (yellow-orange). It can take 2 weeks or longer before the fungus penetrates into the underlying starchy endosperm of the seed (stained blue). Finding out how to make the epicarp resistant to *Fusarium* could be the key to making barley resistant.



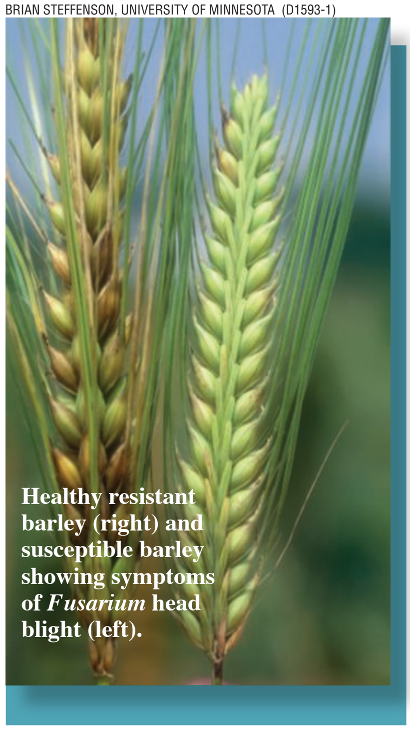
Based on his findings, Skadsen's team developed gene promoters that can be used to "turn on" genes that defend against *Fusarium* in these susceptible tissues. The promoters—from barley genes *Lem1, Lem2, and Ltp6*—are attached to barley antifungal genes to turn them on at specific locations.

"Knowing which parts of the barley plant *Fusarium* attacks gives us insight into how the infection process works," says Skadsen. "We now know where to knock out *Fusarium* in the early stages of infection, which will aid targeted breeding and biotechnology strategies for making barley resistant."

Previous studies examining *Fusarium* infection found that the fungus will liquefy the starchy part of the seed within 5 days after infection. But these studies used detached seeds. Skadsen found that, even 16 days after infection, *Fusarium* does not penetrate the starchy endosperm when the seed remains attached to the spike. This means breeders can focus on looking for traits that will prevent or head off the fungus's early penetration.

Skadsen and research leader Cynthia Henson are also looking to understand the biochemistry of susceptible barley tissues through metabolic profiling during the first 3 days of infection. They found that there is a shift in sugar levels, especially the appearance of and rapid increase in the sugar alcohol ribitol, a metabolite that has not been extensively studied. The scientists are next looking to see whether the shifts in various sugar levels are caused by the plant's mobilizing sugar away from the infection point or by the fungus's taking specific sugars and metabolites away from the plant through feeding. They hope these results will inform researchers how *Fusarium* alters the metabolism of barley tissues to optimize its own nutrition.

BRIAN STEFFENSON, UNIVERSITY OF MINNESOTA (D1593-1)



Healthy resistant barley (right) and susceptible barley showing symptoms of *Fusarium* head blight (left).

Marker-Assisted Breeding of Scab-Resistant Barleys

Shiaoman Chao and her team at an ARS genotyping laboratory in Fargo, North Dakota, work closely with small-grains breeders in the Northern Plains region to use marker technologies to improve crops. Chao, a molecular geneticist, uses current genomics information to develop DNA markers tagged to important agronomic traits. Once appropriate markers are identified, they can be used in breeding populations to increase the efficiency of selection.

"At Fargo, we provide genotyping service to all small-grains breeders located in the region," says Chao, who is in the ARS Cereal Crops Research Unit.

Rich Horsley at North Dakota State University (NDSU) and Kevin Smith at the University of Minnesota (UMN) are key collaborators in Chao's work, providing breeding lines for the ARS Fargo team to do the genotyping.

To accelerate the rate of deployment of genes for resistance to scab using marker technologies, the Fargo lab has developed a sample preparation protocol and high-throughput genotyping procedures that are both efficient and cost effective for carrying out marker-assisted breeding.

Breeders send samples generated in their breeding programs by inserting leaf clippings into 96-well plates provided by Fargo lab. Much of the genotyping process has been semi-automated through use of robotic instruments.

High-throughput DNA extraction and marker genotyping protocols can help scientists conduct genetic mapping studies with large populations. This has been important in mapping scab resistance in barley because three of the most important resistance genes in barley are located very close to

U.S. Wheat and Barley Scab Initiative and Barley Coordinated Agricultural Project

Protecting barley from disease and developing improved varieties involves coordinated USDA research supported by both intramural and competitive grants programs. As a prime example, ARS manages the U.S. Wheat and Barley Scab Initiative (USWBSI), targeted to combating the most devastating disease of barley and wheat in North America. ARS has joined with researchers, producers, millers, and processors to develop a pragmatic action plan to minimize the threat of *Fusarium* head blight (FHB), sometimes called "scab."

A major goal of the USWBSI is to develop FHB-resistant barley varieties with good malting quality. ARS intramural researchers are partnering with more than 75 scientists receiving USWBSI competitive grant awards from 22 universities and international organizations in coordinated efforts to combat FHB and advance food safety and security. The action plan and more information on the USWBSI can be found at scabusa.org.

Barley breeding is being advanced by the Barley Coordinated Agricultural Project (CAP), supported by USDA's Agriculture Research Funding Initiative, a collaborative effort of 30 scientists from 19 institutions, including ARS, that leverages genomics information and technology to advance barley breeding. Research in barley genetics/genomics, breeding, pathology, food science, and statistics makes up CAP. More information is available at barleycap.org.

undesirable genes, which creates a substantial problem for breeders. But it can be overcome by screening very large populations with markers and identifying progeny in which the undesirable traits are unlinked from the resistance trait.

Chao screens breeding lines with resistance to scab using DNA markers previously identified as linked to the resistance genes in both wheat and barley. She also works on DNA markers for other traits, such as protein quality and resistance to leaf rust and tan spot in wheat and resistance to net blotch and *Septoria* speckled leaf blotch in barley.

"Creation of the ARS genotyping centers has dramatically changed the way small-grains breeders think about using DNA markers in breeding," says Smith, who runs the barley breeding project at UMN. "There, the genotyping is done at a scale and speed that would not be possible if left to individual breeding programs."

STEPHEN AUSMUS (D1590-11)

Inside a growth chamber, molecular biologist Ron Skadsen uses an immersion technique to inoculate barley seed spikes with spores from a strain of *Fusarium graminearum*.

USWBSI Projects in North Dakota Take Shape

There are a total of 145 USWBSI projects in all research categories, according to the initiative's manager, Sue Canty. Among USWBSI's top objectives is the reduction of mycotoxins. This is important to the producers, processors, and consumers of wheat and barley.

Rich Horsley, a professor and barley breeder at NDSU, has been using his USWBSI grant for development of improved six-rowed and two-rowed germplasm. Horsley is also coordinating a *Fusarium* head blight (FHB) nursery at Zhejiang University in Hangzhou, China. Highlights include advancement of the six-rowed barley breeding line ND20448 into the final stages of plant-scale malting and brewing evaluation by the American Malting Barley Association, Inc. (AMBA).

Horsley has collaborated with Chao on mapping quantitative trait loci that confer resistance to scab and reduce accumulation of the mycotoxin known as "deoxynivalenol." Identification of markers useful for screening across the multiple pedigrees and genetic backgrounds used by the NDSU barley breeding program has been unrealized until 2009. In the past, markers would work in some populations and not others. Using markers identified in research conducted by collaborators at UMN, Chao was able to genotype all six-rowed lines used as parents in crosses the past 4 years and all six-rowed lines grown in yield trials in the summer of 2009.

Data provided by Chao has allowed Horsley's program to be more efficient in selecting lines as parents for this fall's crossing block, planning which crosses to make, and determining which lines should be candidates for advancement to 2010's yield trials.

The project's goal for 2010 is to submit to Chao's laboratory leaf tissue from early-generation lines so the research team can determine which lines to advance for further testing in the breeding program.

Scab is a major factor in the decline of malting barley production to historic lows in the Dakotas and Minnesota, key states for raw material for the U.S. malting and brewing industry. "Research outputs from the USWBSI are expected to help address the production decline, reducing the need to source malting barley long distances," says AMBA president Mike Davis.

CAP Program Key to Developing Elite Barley Germplasm

The focus of Coordinated Agricultural Project (CAP) research is to identify molecular markers that will speed up barley breeding efforts. The novelty of this approach is that mapping of important traits is done using contemporary breeding populations. The result is that breeding and mapping are done in parallel, accelerating translation of genetic information useful to plant breeding. Begun in 2005, CAP has already identified genetic markers associated with malting quality traits, winter hardiness, and resistance to scab. (For more information about ARS's malting-quality work, see the story on page 7 of this issue.)

The goal of CAP is to detect single-nucleotide polymorphism (SNP) variations located at 3,072 different positions in the genomes of 3,840 barley breeding lines studied over a 4-year period. To detect these genetic variations, the Fargo lab is using a high-throughput genotyping system—a speedy and efficient way of analyzing SNPs—that's capable of analyzing SNPs located at 1,536 positions of 96 individuals in a single reaction assay.

Chao is ARS's lead scientist in CAP. Her team in Fargo carries out the high-throughput genotyping to generate 10 million data points. CAP participants mine this data and identify markers for barley improvement. The results have been published in scientific papers on evaluating the genetic diversity present among U.S. barley breeding programs. All findings in identifying SNP markers closely associated with various agronomic traits, such as scab resistance, are made publicly available to assist all barley breeders.—By **Alfredo Flores** and **Stephanie Yao,** ARS.

This research is part of Plant Diseases (#303), Plant Biological and Molecular Processes (#302), and Plant Genetic Resources, Genomics, and Genetic Improvement (#301), three ARS national programs described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Alfredo Flores, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1627, alfredo.flores@ars.usda.gov. ✷

Like Malt?

You'll Love This Malting Barley Research!

If you've always thought that snacking on those little chocolate malt candies at the movies is half the fun of going to the theater, read on!

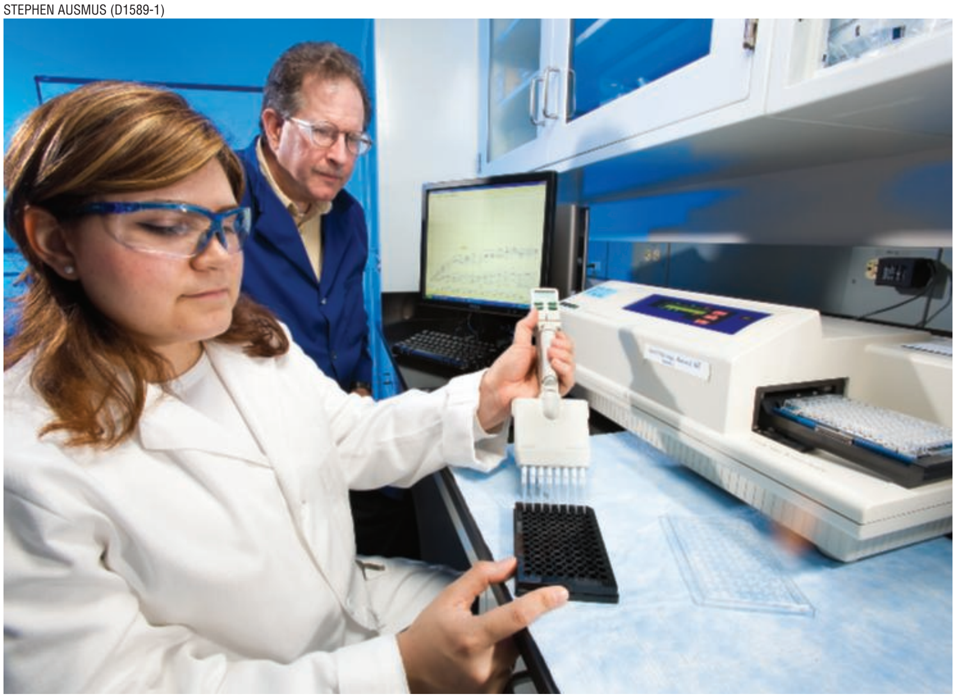
You'll be glad to know that malting barleys—the ones used for making malt for breakfast cereals, candies, beer, and other favorite foods and beverages—are the focus of research by two ARS experts at Madison, Wisconsin. Chemist Mark Schmitt and plant physiologist Allen Budde, with the agency's Cereal Crops Research Unit, are discovering more about what goes on inside little barley kernels germinating in the malt house. It's those kernels that give us the smooth, delicious flavors of malt.

Findings from the scientists' basic and applied research help plant breeders develop even better malting barleys for tomorrow. Of particular interest to Schmitt are the enzymes the kernel creates while it is sprouting. These specialized enzymes, for example, disassemble stored proteins into their component amino acids and convert stored carbohydrates into molecules called "simple sugars."

Schmitt is also interested in the balance of this protein-carbohydrate breakdown. Why the interest? Because the balance can affect malt's flavor and other attributes.

In a 2008 issue of the *Journal of Cereal Science,* Schmitt documented a study that not only provided new insight into the interplay of the enzymes, but also led to follow-up studies in progress at his lab today. In the published research, Schmitt worked with protein-degrading enzymes known as "serine-class proteases." He found that they can degrade another enzyme, beta-amylase, a key player that degrades carbohydrates. The finding is notable because it showed, for the first time, that a protein-degrading enzyme in a grain kernel can digest an important, carbohydrate-degrading enzyme.

STEPHEN AUSMUS (D1589-1)



Chemist Mark Schmitt and biologist Leslie Zalapa prepare a 96-well microplate for use in high-throughput assays of barleys being evaluated for their malting potential.

Hints of an interesting interaction between serine-class proteases and beta-amylase began to emerge in a study Schmitt reported in 2007 in the journal *Cereal Chemistry.* In that survey of more than 2,000 North American malting barleys, Schmitt and Budde found an unexpected correlation between high levels of a desirable beta-amylase-associated attribute and low levels of serine-class proteases. The later discovery that serine class proteases can digest beta-amylase offers a possible explanation for this inverse correlation.

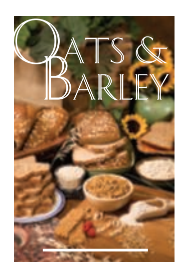
"This all goes to show that we have a lot more to learn about the subtle interplay of the barley kernel enzymes during germination in the malt house and how the activity and balance of the enzymes affects the quality of the malt," Schmitt says.

It's research that should help barley breeders everywhere stay steadily on track in their quest to produce malting barleys that are superior even to today's very best.

For us malted milk fans, that's good news, indeed.—By **Marcia Wood,** ARS.

This research is part of Quality and Utilization of Agricultural Products, an ARS national program (#306) described at www.nps.ars.usda.gov.

Mark Schmitt and Allen Budde are in the USDA-ARS Cereal Crops Research Unit, 502 Walnut St., Madison, WI 53726; (608) 262-4480 (Schmitt), (608) 262-4483 (Budde), mark.schmitt@ars.usda.gov, allen.budde@ars.usda.gov. ✷



International Wheat and Barley Screening Collaboration Helps Uncover Stem Rust-Resistant Material

DAVID MARSHALL (D1594-1)

DAVID MARSHALL (D1595-1).

In Njoro, Kenya, a barley infected with stem rust (left) and one that is resistant.

The Njoro Research Center of the Kenya Agricultural Research Institute (KARI) has been a hotbed of activity these past few years. Since 2005, plant scientists from research organizations around the world, including the Agricultural Research Service, have been sending their countries' top wheat cultivars and experimental lines to Njoro for testing against Ug99, *Puccinia graminis f. sp. tritici,* the most virulent race of the stem rust fungus yet to emerge.

Screening of ARS-sent wheat is carried out under a specific cooperative agreement with KARI and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. ARS, KARI, CIMMYT, and other organizations partner with the Borlaug Global Rust Initiative, an international effort to speed the development and delivery of new rust- and Ug99-resistant cultivars to affected small-grains farmers. The work is especially important to subsistence farmers in parts of Africa and the Middle East where the disease has already arrived and to nations in Ug99's likely path of spread.

To date, more than 12,000 lines of U.S. wheat—and, to a lesser degree, barley—have been screened, mainly at KARI field plots in Njoro, considered a Ug99 epicenter after the new rust strain was first detected there in 2001. Similar screening takes place at the Kulumsa and Debre Zeit Research Stations in Ethiopia.

Evaluating U.S. Wheat Germplasm

Mike Bonman, research leader of ARS's Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, oversees rust research conducted by molecular biologist Eric Jackson, agronomist Harold Bockelman, plant pathologist Blair Goates, and postdoctoral plant pathologist Maricelis Acevedo. Goates coordinates the acquisition and shipment of seed for testing. These shipments mainly include advanced breeding lines and heirloom varieties (or landraces) of durum and bread wheats acquired from public and private donors and maintained in ARS's National Small Grains Germplasm Collection, also at Aberdeen.

PEGGY GREB (D948-1)

Plant pathologist Mike Bonman (left) and molecular biologist Eric Jackson examine wheat plants from the National Small Grains Collection in a stem rust screening plot at Aberdeen, Idaho.

"We're focusing on these first because heirloom spring varieties are easiest to manipulate (use in plant breeding) and perhaps more likely to have novel sources of resistance genes," says Bonman.

Prescreening of seedlings against local rusts at Aberdeen—and previous evaluations conducted with U.S. races on adult plants at ARS's Cereal Diseases Laboratory in St. Paul, Minnesota—helped narrow the list of wheat destined for Kenya, based on the plants' responses to the fungal disease.

As expected, only the toughest of the tough survived the testing at Njoro. Of 1,768 heirloom wheats submitted since 2005, only 78 (or 4.4 percent) showed resistance to Ug99 at the Njoro site. Still, the prescreening led to identification of more

Ug99-resistant wheat accessions than would've been achieved from sending randomly selected accessions for testing, says Bonman. This is evidenced by the fact that 7 percent of wheat lines resistant to U.S. races showed rust resistance in Kenya, yet only 1 percent of randomly selected accessions did.

Given Ug99's reputation as a conqueror of known rust-resistance genes, finding at least some resistance was encouraging—even more so if the survivors are found to harbor new, uncharacterized antirust defenses.

"Some of the landrace accessions we've screened in Kenya have shown intermediate to high levels of resistance," says Acevedo, who also collaborates with ARS plant pathologist Yue Jin at St. Paul. "We're now crossing these landraces with cultivated wheat to study the inheritance of the resistance and to obtain genetic data from them by using molecular-marker technology."

On one front, use of these markers will help determine whether new or previously known rust-resistance genes were behind resistance observed in the Kenya-screened wheats. On another front, the marker technology will equip breeders with a fast, powerful tool for selecting and developing new resistant cultivars for farmers—both in the United States, where Ug99 has not yet arrived, and abroad.

PEGGY GREB (D950-1)

Plant pathologist Blair Goates (left) and agronomist Harold Bockelman prepare seed samples from the National Small Grains Collection to be sent to east Africa for testing against new races of the stem rust pathogen.

New Nursery Houses Rust-Resistant Material

In the next step in the fight against Ug99, the Winter Wheat Stem Rust Resistance Nursery was established by ARS and CIMMYT. The nursery—located in Ankara, Turkey, where CIMMYT coordinates its global winter wheat breeding program—is the first of its kind for winter wheats.

The nursery is a joint effort to distribute 100 lines of winter wheat that have been identified by international scientists as having resistance to Ug99 and its descendants. Thirty of the 100 lines were developed by ARS scientists and have been identified as being resistant to stem rust in Kenya and to U.S. stem rust races.

"We have molecular markers that allow us to predict the presence of some resistance genes. But the resistance must be confirmed in the field in Kenya or at other locations where the pathogen exists," says David Marshall, research leader of the ARS Plant Science Research Unit in Raleigh, North Carolina, and coordinator of the screening conducted at KARI.

Germplasm from the nursery is currently being distributed to wheat breeders and geneticists in 34 countries around the world. The ARS breeding effort focused on the use of four or five resistance genes, which have been incorporated in various combinations into winter wheat lines. Multiple genes for resistance, according to Marshall, will slow the pathogen's ability to readily overcome the new varieties breeders develop. While these are all experimental lines, some could be used in the field as cultivars.

"How long these genes can remain effective is key to maintaining resistance to stem rust in the United States," says Marshall. "The rust pathogen is a moving target; mutations may arise that can overcome the resistance genes. It is of paramount importance that we maintain and accelerate our breeding efforts to keep ahead of this ever-changing pathogen."

Scientists are also screening barley lines for resistance to stem rust. Though this research is not as advanced as that on wheat lines, Marshall and colleagues have identified several sources of resistance in barley lines currently being tested in Kenya. These lines still need another year of field evaluations before the scientists can confirm their resistance.

Fighting stem rust is truly a team effort. Besides Raleigh, Aberdeen, and St. Paul, other ARS locations involved in rust research include the Plant Science and Entomology Research Unit in Manhattan, Kansas, and the Cereal Crops Research Unit in Fargo, North Dakota.—By **Stephanie Yao** and **Jan Suskiw,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301) and Plant Diseases (#303), two ARS national programs described at www.nps.ars.usda.gov.

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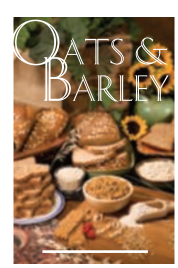
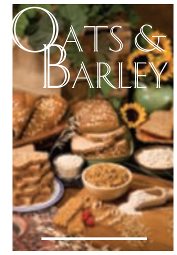


Oats

Cooling Inflammation and Unhealthy Cell Proliferation



Health-conscious consumers long have chosen meals that include oats—in part due to a snappy "heart healthy" claim that prominently appears on the labels of packaged oat products sold nationwide. Significantly, ARS-funded scientists have not only discovered that certain compounds in oats hinder the ability of blood cells to stick to artery walls, but they have also found further indicators that the same compounds hold promise to provide other health benefits.

This research is led by nutritionist Mohsen Meydani, director of the Vascular Biology Laboratory at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University (HNRCA) in Boston, Massachusetts. Meydani previously showed that phenolic antioxidants in oats actually obstruct the ability of blood cells to stick to artery walls. He showed that the compounds, called "avenanthramides," from oats significantly suppress the adhesive molecules that glue blood cells to artery walls.

Now, Meydani has been working on determining the anti-inflammatory and other effects of oat avenanthramides and their derivatives. He is using several animal models and colon cancer cell lines for testing purposes. As a result of using these models, Meydani has published several journal articles that shed light on the compounds' potencies and molecular mechanisms.

A 2006 study published in the journal *Free Radical Biology & Medicine* demonstrated for the first time that avenanthramide-c arrests smooth muscle cell (SMC) proliferation, which is known to participate in arterial lesion development. Unhealthy SMC growth contributes to the development of atherosclerosis, which can eventually lead to heart attack. Also, vascular endothelial cells, and to a lesser degree SMCs, are involved in the synthesis of heart-healthy nitric oxide. The researchers found that avenanthramide-c treatment of human SMC significantly and dose-dependently increased nitric oxide production in both SMC and endothelial cells.

These results suggest that the avenanthramides of oats may contribute to the relaxation of arteries and the prevention of atherosclerosis by increasing nitric oxide production and inhibiting SMC proliferation. In fact, earlier human clinical studies conducted by Meydani's colleagues at the HNRCA have shown that consumption of oats reduces blood pressure.

Another 2008 study, also published in *Free Radical Biology & Medicine,* reported findings that suggest that avenanthramides decrease expression of inflammatory molecules. Because chronic inflammation of the arterial wall is part of the process that eventually causes disease, inhibition of inflammation through diet, drugs, or key nutrients is considered to be of great benefit in preventing atherosclerosis.

PEGGY GREB (D1678-1)

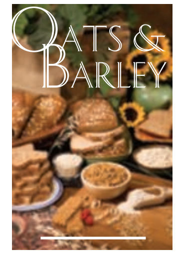
ARS-funded research at the Human Nutrition Research Center on Aging at Tufts University shows potential health benefits of oat consumption beyond the prevention of coronary heart disease through lowering blood cholesterol.

Findings from a more recent study soon to be published suggest that consuming oats and oat bran may reduce the risk of colon cancer, not only through high fiber content, but also through avenanthramides that slow or discourage proliferation of colon cancer cells.

These studies provide additional indications of the potential health benefit of oat consumption in the prevention of coronary heart disease beyond its known effect through lowering blood cholesterol.—By **Rosalie Marion Bliss,** ARS.

This research is part of Human Nutrition, an ARS national program (#107) described at www.nps.ars.usda.gov.

Mohsen Meydani is with the USDA-ARS Vascular Biology Laboratory, Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University, 711 Washington St., Boston, MA 02111-1524; (617) 556-3126, mohsen.meydani@tufts.edu. ✷



Barley Examined as Source for Potential Fish Feed

Millions of tons of menhaden and other small fish are removed from the oceans each year to feed fish, poultry, and swine. The total amount of fish harvested for fishmeal has not changed in the last 20 years, but the demand has increased sharply. This pressure is thought by some to presage ecological problems and higher feed costs. So the search is on for alternative feed ingredients.

ARS scientists, led by fish physiologist Rick Barrows, are attacking the problem from many angles, one of which is to use barley protein as a main ingredient in feeds. Researchers at the Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, are examining barley's genes to improve the grain's protein yield and nutritional composition and developing ways to concentrate the protein. At the research unit, which is co-located at the University of Idaho's Hagerman Fish Culture Experiment Station, geneticist Ken Overturf is identifying genes in trout that may allow the fish to better utilize fishmeal-free diets.

The research team is pursuing several approaches to enhance the use of barley protein in aquafeeds. One is to produce a highly valuable co-product, beta-glucan, for the human nutraceutical industry while also producing barley protein for fish. Geneticist Gongshe Hu has selected varieties that will yield high levels of beta-glucan as well as protein.

Another approach is to concentrate the protein in standard field barley into a form usable in aquaculture feeds. Keshun Liu, a chemist at Aberdeen, is evaluating both wet and dry fractionation methods of concentrating the protein. Barrows and researchers with cooperative research and development agreement partner Montana Microbial Products (MMP) of Butte, Montana, applied for a patent on a new enzymatic method that concentrates barley protein and produces raw material for another valuable commodity—ethanol.

"This process has provided a high-protein ingredient that may replace other, more expensive protein sources," says Barrows.

"We conducted feeding trials to determine the digestibility of macronutrients and amino acids in the barley protein concentrate. The data from these trials allowed us to formulate trout feeds with varying levels of barley protein concentrate, and we successfully replaced both fishmeal and soy protein concentrate.

"There is no current commercialization of barley protein concentrate in place, but MMP is producing pilot quantities for feeding studies in trout, salmon, and other species. MMP projects that the concentrate will sell for $700 to $1,200 per ton," says Barrows. Since fishmeal costs about $1,200 per ton, and fish oil costs about $2,200 per ton, the projected costs of barley protein concentrate compare favorably.

"Feed is part of a complex interplay of genetics, nutrition, and economics," says Barrows. "We believe barley protein concentrate can completely replace fishmeal if other essential nutrients are supplemented. We will also examine oats as another fish-feed alternative."—By **Sharon Durham,** ARS.

This research is part of Aquaculture, an ARS national program (#106) described at www.nps.ars.usda.gov.

Rick Barrows is in the USDA-ARS Small Grains and Potato Germplasm Research Unit, 3059 F National Fish Hatchery Rd., Hagerman, ID 83332; (406) 994-9909, rick.barrows@ars.usda.gov. ✷

STEPHEN AUSMUS (D1425-9)

Fish physiologists Rick Barrows (left) and Gibson Gaylord (right) inspect pellets made of barley protein as technician Jason Frost (background) loads an extruder with raw materials.

Markers Point the Way to New Oat Traits

DOUG WILSON (K3942-6)

America's oat production has decreased since the 1950s, but consumer demand remains as strong as ever, especially with mounting scientific evidence that oats are good for us.

Their soluble fiber, beta-glucan, for example, appears to reduce blood-cholesterol levels and has been formulated for use in food and beverage products. The grain has nonfood applications, too, including use of oat flour in skin- and hair-care products.

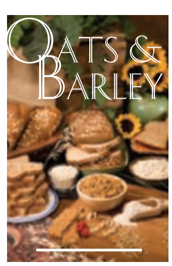
Now, a concerted effort to furnish oat breeders with the latest tools in molecular genetics could make even better use of such versatility, broadening the cereal grain's commercial horizons and increasing its production.

"Genomically, oat has lagged behind other cereal crops, like corn and barley," says molecular biologist Eric Jackson, who is in the Agricultural Research Service's Small Grains and Potato Germplasm Research Unit at Aberdeen, Idaho. But an oat-genomics project he and ARS geneticist Don Obert (Aberdeen) proposed in late 2008 to address the deficit has quickly gained momentum, thanks to the participation of 2 ARS Regional Molecular Genotyping Laboratories, 5 other ARS locations, 10 U.S. universities, 9 foreign laboratories, and support from General Mills, Inc., members of the North American Millers' Association (NAMA), and the USDA-Agriculture and Food Research Initiative's Plant Breeding, Genetics, and Genomics program.

"NAMA has long supported efforts to bring new tools to oat researchers," says Jane DeMarchi, the association's director of government relations. "We believe this project will help ensure that oats remain a viable crop."

A key objective is to provide oat breeders with a fast, accurate means of identifying valued traits in elite commercial cultivars and germplasm sources. To that end, the group is scouring the oat genome for DNA marker regions associated with the expression of these traits. Of particular interest are increased dietary fiber content, elevated levels of grain beta-glucan and tocopherol, and improved disease resistance.

The markers—small pieces of DNA—are like molecular signposts pointing out a desired trait's genomic whereabouts. Several different kinds can be used, but the type the oat genomics group seeks is the SNP (single nucleotide polymorphism). The aim is to find and describe (through sequencing thousands of expressed genes in important North American oat varieties) 3,000-plus SNP markers.



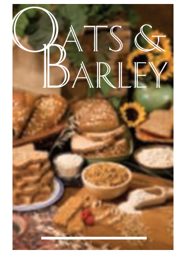
ARS plant geneticist Gina Brown-Guedira (Raleigh, North Carolina) and ARS molecular biologist Joe Anderson (West Lafayette, Indiana) will develop diagnostic assays from the newly discovered marker-trait associations. This, in turn, will enable use of marker-assisted selection (MAS) to accelerate the development of new oat varieties with enhanced benefits to human health. Brown-Guedira's genotyping lab will then use the assays to quickly inform breeders which offspring plants inherited an intended trait—say, for crown rust resistance. Normally, determining this trait would necessitate growing the plants to maturity, inoculating them with the pathogen, waiting for disease symptoms to appear, and evaluating the plants' response. But with MAS, resistant plants could be identified in about 3 days based on high-throughput DNA analyses using diagnostic markers.

Another goal, pursued by ARS geneticist Jean-Luc Jannink (Ithaca, New York), is to develop a predictive computer model oat breeders can use to forecast which candidate varieties will perform best, whether it be for food, feed, or industrial uses.—By **Jan Suszkiw,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement, an ARS national program (#301) described at www.nps.ars.usda.gov.

To reach scientists featured in this article, contact Jan Suszkiw, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1630, jan.suszkiw@ars.usda.gov. ✸

Finding Crown Rust Resistance That Can Go the Distance, in Oats



Crown rust is the most damaging fungal disease of oats in the world, wiping out entire fields and causing epidemics that can reduce yields up to 40 percent. But the disease may have met its match in a slender oat sometimes listed as a noxious weed.

Geneticists have been trying to combat crown rust for years by taking resistance genes from wild oats and inserting them into domestic varieties, where they produce proteins believed to recognize specific strains of crown rust and attack them. They have also developed multiline cultivars with several resistance genes.

Crown rust is caused by *Puccinia coronata,* a fungal pathogen that reproduces both sexually and asexually, giving it a genetic flexibility capable of countering such plant defenses. Research at the ARS Cereal Disease Laboratory in St. Paul, Minnesota, shows that crown rust will usually overcome resistance genes in about 5 years, making both the single gene and the multiline approaches unsustainable. A study by Martin L. Carson, the laboratory research leader, also shows that crown rust is increasing in virulence throughout North America and is able to overcome more and more of the 90 known resistance genes available to breeders. Carson also found that in an oat multiline cultivar with 10 resistance genes, crown rust is now able to overcome all 10 of them. "We've exhausted all the known single genes available for resistance in domestic oats," he says.

To find new genes for resistance, Carson is looking to a wild variety, *Avena barbata,* listed as a noxious weed in Missouri and classified as moderately invasive in California. The slender oat grows wild in South Asia, much of Europe, and around the Mediterranean region, and genes from it have been transferred into cultivated oats to build resistance to powdery mildew and stem rust. But its genes for resisting crown rust are largely untapped.

Carson inoculated 359 *A. barbata* accessions, grown from seed maintained at the ARS National Small Grains Collection in Aberdeen, Idaho, with a very diverse mix of crown rust strains from the University of Minnesota buckthorn nursery. Buckthorn is the alternate host of crown rust and is where the fungus sexually recombines. He evaluated the plants in greenhouses, and after several crosses, he found seedlings highly resistant to a wide variety of crown rust strains. In ongoing studies, he is crossing them with the domestic oat, *A. sativa,* to try to develop the right blend of resistance and desirable traits, such as high yield, drought resistance, durability, and taste.

Such crossbreeding efforts pose a major challenge. The domestic oat has 42 chromosomes, but *A. barbata* has 28 chromosomes, and that makes it more difficult to cross the two oats and ensure reliable transfers of specific genes. Carson and his colleagues are addressing that obstacle by crossing *A. barbata* with another wild species, taking the hybrid from that pairing, and crossing it with the progeny of other wild and cultivated crosses.

Carson is also taking a new approach: developing an oat variety with a more durable form of resistance called "partial," "slow-rusting," or "adult plant" resistance. With this type of resistance, the oat plant allows crown rust to survive on it, but the disease develops slowly, making it less damaging. The goal is a new oat line for breeders to use in developing varieties that can fight off crown rust for a long time.—By **Dennis O'Brien,** ARS.

This research is part of Plant Diseases (#303), an ARS national program described at www.nps.ars.usda.gov.

Martin L. Carson is with the USDA-ARS Cereal Disease Laboratory, 1551 Lindig St., St. Paul, MN 55108; (612) 624-4155, marty.carson@ars.usda.gov. ✷

STEPHEN AUSMUS (D1582-5)

Plant pathologist Martin Carson (left) and technician Jerry Ochocki inspect crown rust infections on common buckthorn, an alternate host. Multiple varieties of oats are planted between rows of infected buckthorn to determine which varieties can resist crown rust.

Hulled winter barley ready for harvest.

Boosting Barley for Bioenergy

Agricultural Research Service (ARS) scientists Kevin Hicks and David Marshall want winter barley to become a prime-time player in bioenergy production.

"The 2007 Energy Independence and Security Act requires production and use of 36 billion gallons of renewable transportation fuels by 2022. Today we only make 9 billion," says Hicks. "We see winter barley as the perfect biofeedstock for making biofuels on the East Coast."

So Hicks and others in the ARS Crop Conversion Science and Engineering Research Unit in Wyndmoor, Pennsylvania, are developing new sustainable technologies to convert varieties of hulled and hull-less winter "energy" barley into fuel ethanol. This initiative also includes Virginia Polytechnic Institute and State University scientists Carl Griffey, Wynse Brooks, and Mark Vaughn, who are supervising ongoing research efforts to develop improved varieties of hulled and hull-less barley.

Their combined efforts could help farmers from southern Pennsylvania to South Carolina develop a profitable 2-year rotation of winter barley, corn, and soybeans. Winter barley is grown on seasonally fallow land. It acts as a cover crop by protecting soil and nutrients and preventing migration of fertilizers from crop fields to the Chesapeake Bay—which is why the Chesapeake Bay Commission supports the development of winter barley as an energy crop. And since the field would otherwise be left fallow, producing biofuels from winter barley would not interfere with food production.

Now, too, there is a major marketing opportunity for growers of winter barley. Osage Bio Energy, headquartered in Glen Allen, Virginia, is well under way in constructing the first major barley-to-ethanol production facility in the United States.

Meanwhile, in Raleigh, North Carolina, Marshall coordinates the regional winter barley testing nursery, which has the best experimental lines from both public and private winter barley breeding programs in the United States. He and other scientists in the ARS Plant Science Research Unit are just a few years into making crosses between hull-less barley and barley with resistance to Ug99, a stem rust that can inflict crop losses of up to 100 percent.

Once the researchers have developed robust lines that contain both traits, they'll begin breeding for traits to enhance ethanol production, such as starch content. "In several years, we hope to release barley varieties with traits for enhanced agronomic performance, good grain-to-ethanol qualities, and good resistance to stem rust," Marshall says.—By **Ann Perry,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301), Bioenergy and Energy Alternatives (#307), and Quality and Utilization of Agricultural Products (#306), three ARS national programs described at www.nps.ars.usda.gov.

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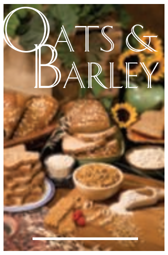
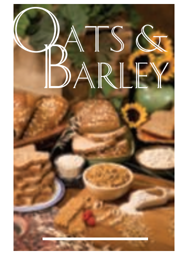
David S. Marshall is in the USDA-ARS Plant Science Research Unit, North Carolina State University, 3411 Gardner Hall, Raleigh, NC 27695; (919) 515-6819, david.marshall@ars.usda.gov. ✷





Uncovering the Nutritional Value of Oats

Oats have been widely touted for their many health benefits to humans. In part, these benefits are likely derived from avenanthramides (Avns), a metabolite with potent antioxidant properties found exclusively, among food crops, in oats.

At the Cereal Crops Research Unit in Madison, Wisconsin, chemist Mitchell Wise is exploring the full extent of the biological function Avns have in oats. Previous studies have found that an Avn-enriched diet boosted antioxidant activity in serum and certain tissues in mammals, including humans. Insight into how Avn production is regulated may lead to increased Avn levels in the grain, which could, in turn, lead to higher antioxidant levels in the foods we eat.

The specific purpose of Avns is still largely unknown, but previous studies have found an increased production of Avns in oat leaves when the plant is attacked by a fungus, leading researchers to believe it plays an antimicrobial role.

But the amounts of individual Avns, says Wise, are highly variable and appear to be strongly affected by environment, genotype, and genotype-environment interactions. Wise and colleague Doug Doehlert, a fellow chemist with the ARS Red River Valley Agricultural Research Center in Fargo, North Dakota, examined the correlation between crown rust pressure and Avn concentration in the grain. They tested 16 oat cultivars and 2 breeding lines at three locations in North Dakota over 2 years.

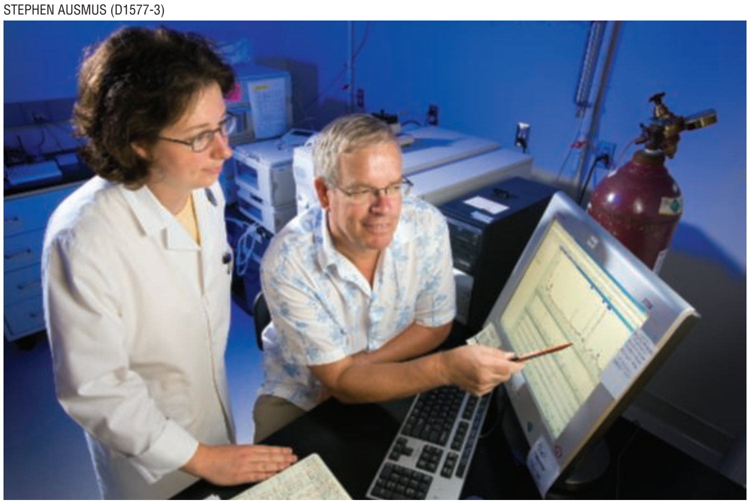
The researchers found genotypes with the strongest crown rust resistance typically had the highest Avn concentrations in environments where crown rust occurred. They also found Avn production is likely influenced by additional environmental factors, as not all cultivars with strong crown rust resistance produced high Avn concentrations. Nevertheless, their results suggest that oat breeders—taking into account crown rust pressure during growth—can select certain cultivars for enhanced production of Avns.

Wise is also making an important contribution to human nutrition studies involving oats. Though there are at least 25 structural varieties of Avns found in oats, three forms—avnA, avnB, and avnC—are most abundant in the grain. Wise is able to create pure synthetic compounds of each type, which he supplies to colleagues for use in nutrition studies. Recently, Avns have been found to help reduce the risk of heart disease. (See story on page 10.)

STEPHEN AUSMUS (D1576-14)

Chemist Mitchell Wise works with phenolic extracts from oats to evaluate their avenanthramide content.

STEPHEN AUSMUS (D1577-3)



Technician Rachel Angel and Mitchell Wise examine a chromatogram of extract from oats to evaluate avenanthramide content.

In his lab, Wise is further researching the biosynthesis of Avns. He developed a suspension culture system from oat shoot tissue in which Avns are produced in response to a chemical that mimics fungal infection. The suspension cultures produce large amounts of avnA and avnG and, under certain culture conditions, avnB and avnC.

"This system is a new tool that can be used for more detailed investigation into how certain Avns are produced," says Wise. "Once refined, the system has the potential to create individual Avns for further study."—By **Stephanie Yao,** ARS.

This research is part of Plant Biological and Molecular Processes, an ARS national program (#302) described at www.nps.ars.usda.gov.

Mitchell Wise is in the USDA-ARS Cereal Crops Research Unit, 502 Walnut St., Madison, WI 53726-2335; (608) 262-9242, mitchell.wise@ars.usda.gov. ✷

All-Oat, All-Barley Breads Ahead? Maybe!

New interest in tasty, all-oat or all-barley breads might be sparked by the laboratory experiments now being conducted by chemist Wallace Yokoyama and postdoctoral nutritionist Hyunsook Kim. These delicious, healthful breads could appear on bakery or supermarket shelves that today are dominated by wheat flour-based loaves, yet would provide a different array of vitamins, antioxidants, fiber, protein, and other components that "aren't present in whole-wheat breads," says Yokoyama.

"The large variety of multigrain loaves currently available in U.S. supermarkets and bakeries suggests that people have a growing interest in trying new kinds of whole-grain breads," says Kim. Both scientists are with the ARS Western Regional Research Center in Albany, California, near San Francisco.

In preliminary experiments, Yokoyama, Kim, and colleagues used a commercially available, plant-derived fiber known as HPMC (short for hydroxypropyl methylcellulose) as a substitute for the gluten that's present in wheat but lacking in other grains. Gluten nimbly traps the airy bubbles formed by yeast, lifting doughs and yielding high, attractive, nicely textured loaves.

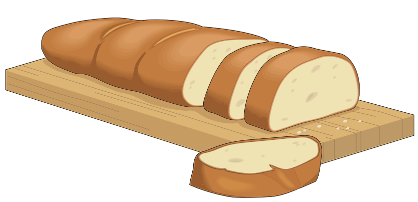
But HPMC performs that essential biochemical chore, too. That was shown many years ago in research, with rice, conducted by now-retired Albany scientist Maura M. Bean.

For their tests, Yokoyama and Kim fed laboratory hamsters a high-fat diet and oat, barley, and wheat breads with HPMC added. They found that the experimental breads had cholesterol-lowering effects.

The HPMC that the scientists are investigating is derived from a plant source proprietary to manufacturer Dow Wolff Cellulosics of Midland, Michigan. Though this HPMC is widely used in familiar foods—as a thickener, for instance—its cholesterol-lowering properties as an ingredient in whole-grain breads haven't been widely studied, says Yokoyama.

The Albany studies may ease oats and barley into the supermarket and bakery spotlight, giving these venerable grains a larger role in our meals and snacks—and our health.—By **Marcia Wood,** ARS.

Wallace H. Yokoyama and Hyunsook Kim are with the USDA-ARS Western Regional Research Center, 800 Buchanan St., Albany, CA 94710; (510) 559-5695 (Yokoyama), (510) 559-5755 (Kim), wally.yokoyama@ars.usda.gov, hyunsook.kim@ars.usda.gov. ✷



Oats, Barley, and Wheat: Great Reads and Web Viewing

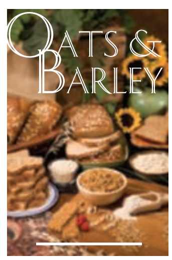
Find a fascinating fact about oats, barley, or wheat—or even an intriguing recipe—in these informative books, websites, and other sources selected by reference librarian Rebecca Mazur at ARS's National Agricultural Library, Beltsville, Maryland:

Barley for Food and Health, by R.K. and C.W. Newman (2008).

Tackle the included recipes for Turkish Barley-Yoghurt Soup, Swedish Barley Sausage, or Danish Pancakes and you'll be appropriately fueled up for perusing this overview on research and development of new, barley-based foods—and much more—presented from a food-maker and food-science perspective.

USDA National Nutrient Database for Standard Reference
nal.usda.gov/fnic/foodcomp/search

Want to know exactly what's inside your breakfast oatmeal? Check out this comprehensive database, generally regarded as the nation's premier analysis of the calories, vitamins, minerals, and other components in familiar foods.



The Small Grains Field Guide, edited by J.J. Wiersma and J.K. Ransom (2005).

Anyone thinking about growing oats, barley, or wheat will want to pick up this 158-page handbook of practical, reliable information from university Extension Service experts in North Dakota and Minnesota.

Barley Science: Recent Advances from Molecular Biology to Agronomy of Yield and Quality, by G.A. Slafer et al. (2002).

A useful anthology of articles about everything from stopping unwanted sprouting of barley kernels before harvest to using wild barleys as a source of genes for superior plants of tomorrow.

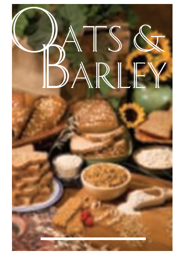
Proceedings, 8th International Oat Conference (2008)
tinyurl.com/oatconf

Leading oat researchers worldwide offer abstracts, posters, and PowerPoint presentations in this preliminary, online compilation from the "Healthy Foods and Healthy Lives" oat conference, a highly regarded forum.

GrainGenes
wheat.pw.usda.gov/GG2/index.shtml

This ARS-curated website offers an enlightening window on the world of those who study the genomes of oats, barley, wheat, and rye, and the wild relatives of these great little grains.

For an industry view, browse this quartet of informative, easy-to-navigate websites: **National Barley Foods Council,** barleyfoods.org; **National Barley Growers Association,** idahobarley.org/nbga; **North American Millers' Association**, namamillers.org; **U.S. Grains Council,** grains.org. ✷



ARS Research Program in Oats and Barley

The Agricultural Research Service's research on oats and barley addresses every facet of safeguarding and improving these important cereal crops, from enhancing our understanding of their fundamental biological processes to breeding varieties for specialized needs to improving production methods.

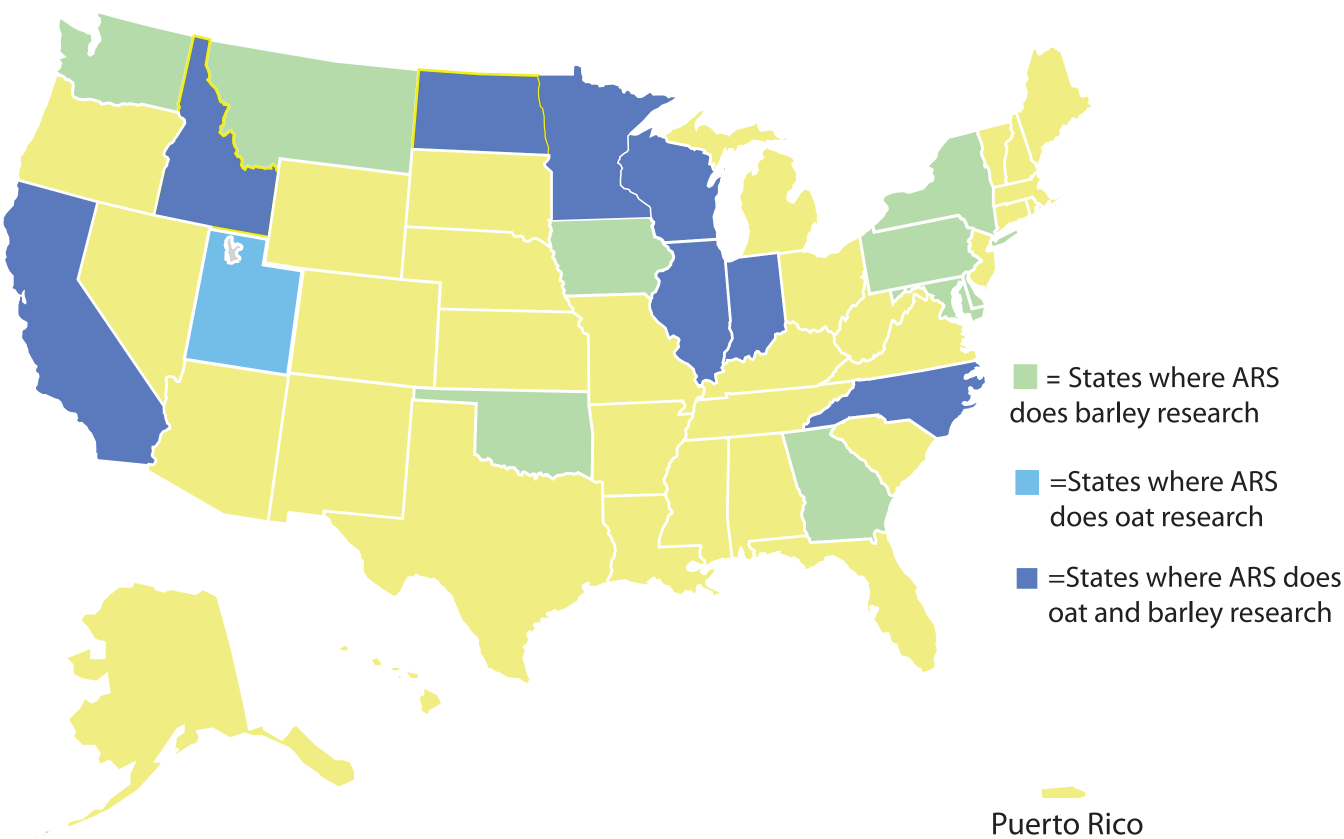
One essential priority of the ARS research program is to find solutions to the critical challenges that new disease and pest problems are posing to oat and barley production in the United States and around the world. ARS scientists are deeply involved in the search for answers to new strains of cereal rust, such as Ug99, stripe rust, and *Fusarium* head blight, along with other emerging viruses and other pests. Finding such answers is key to helping maintain international food security.

ARS also fills a vital role as a leader in collaborations like the ARS-managed U.S. Wheat and Barley Scab Initiative. This initiative pulls together more than 70 federal and university scientists along with farmers and processors. Such partnerships provide opportunities for a nationally coordinated effort to protect wheat and barley from scab losses and help make the most of everyone's limited resources. Similarly, ARS oat researchers are all contributing to a new oat molecular-marker project funded by the USDA National Institute of Food and Agriculture.

Among ARS's unique resources for advancing oat and barley research is the agency's crop genome database, GrainGenes. This database serves as a primary resource for oat and barley researchers and breeders everywhere. Not only is ARS developing and managing the database as a repository of genetic and genomic knowledge, the agency is also identifying many new genetic markers and applying them to improving basic biological processes in oats and barley along with enhancing traits such as disease and pest resistance. For example, ARS researchers are using genomic approaches to improve physiological, biochemical, and genetic regulation of carbohydrate metabolism in cereal tissues as well as finding sources of genetic and biochemical resistance to pathogens such as yellow dwarf virus.

Other ARS research is seeking to improve oats and barley—at the genetic and the processing level—especially to increase the crops' nutritional quality. Among these projects are studies seeking to enlist these cereal grains in the fight to prevent obesity and diseases such as diabetes, particularly in children.

The plan is to tackle the issues facing oats and barley production at every level—from the molecular to postharvest processing—and then use the pool of knowledge generated to find solutions to the problems. ✷



A Range of Plants For Rangeland Rehab

It can take a thousand years for an inch of topsoil to form, and sometimes only a few moments for it to erode away. So at the Agricultural Research Service's Forage and Range Research Laboratory (FRRL) in Logan, Utah, a dozen scientists are finding the best plants and practices for protecting and repairing the fragile soils on the dry rangelands of the western intermountain states.

The FRRL has its roots in early work by U.S. Department of Agriculture scientists who teamed up with U.S. Forest Service scientists in 1907 to manage the range and forests around Logan. FRRL research leader Jack Staub and his team of 11 scientists continue the tradition of working with other state and federal agencies to develop new grasses and forages for pastures, turf, and rangelands.

"FRRL research promotes a balanced program between introduced and native species," says Staub. "This allows people to have a choice in what they want to plant. Land managers in these regions, however, often prefer to use native plants, so one of our main goals is to provide improved native grass and legume cultivars for rangeland restoration whenever we can."

"Our program has been very successful in developing plants for western U.S. rangelands," says FRRL geneticist Kevin Jensen, who has helped develop around 18 new grass cultivars over the past 25 years. "But we also take our research results on the road to growers, stakeholders, and extension agents so that we can educate them about our plant materials and ask for their input."

PEGGY GREB (D1667-1)

In drought-tolerance test plots in Logan, Utah, research leader Jack Staub notes the color, vigor, and persistence of exotic fine-leafed fescue plants collected from Kyrgyzstan. Plants with enhanced drought tolerance could be used for low-input agricultural uses, such as rangeland forage.

A Little Help From the Family

Native plants that once colonized these rangelands are being pushed to the brink by drought, wildfires, overgrazing, extreme temperatures, erosion, mining, military training exercises, and other ecological disturbances. Rangeland managers need to have access to plants that can maintain soil, increase ground cover, and provide forage even in these harsh environments.

Sometimes—especially when the landscape has undergone severe deterioration—it's necessary to use introduced grasses to jump-start the restoration process. Native plants can be brought back into the picture as soil conditions improve.

As part of the long-term restoration process, FRRL scientists often go overseas to gather germplasm to use in developing new cultivars. Prime candidates for collection include a range of grassy relatives that have evolved over millions of years on the South American highlands and Eurasian steppes.

Developing a new plant cultivar, which can take decades, starts with figuring out how the plant will be used. Will it be forage for livestock or wildlife? Will it anchor soils after fire has burned away existing vegetation? Will it keep an invasive annual species—like cheatgrass and medusahead—in check? Or will it need to be all of the above?

Hycrest crested wheatgrass was developed by scientists at FRRL, the Utah Agricultural Experiment Station, and the USDA Soil Conservation Service (now the Natural Resources Conservation Service). Released in 1984, it was the leading crested wheatgrass grown on the western rangelands for around 10 years. It provides forage in early spring and summer, stabilizes soil, holds its own against aggressive invasives, and thrives with as little as 8 inches of precipitation a year.

FRRL scientists have now developed Hycrest II, which was bred for reseeding rangelands that have been overrun by annual weeds after wildfires, soil erosion, or other disturbances. This cultivar offers faster establishment of more seedlings per unit area than Hycrest.

Old World Plants, New World Cultivars

Other rangeland remedies are on the way. Vavilov II is a new Siberian wheatgrass cultivar and a close relative of crested wheatgrass cultivars. Vavilov II, like Hycrest, will help damaged rangelands combat cheatgrass on especially dry and harsh sandy soils. It's already been distributed to six U.S. Department of Defense (DOD) facilities and may end up as part of a seed mix used on more than 40 DOD facilities that sprawl over a million acres.

Russian wildryes, originally from Russia and China, were introduced into the United States in the 1950s in part because they withstand drought more readily than crested wheatgrass. FRRL scientists have been breeding varieties of Russian wildrye since 1981 and have improved its relatively slow seedling growth and development. In 2006, they announced the release of Bozoisky-II, a Russian wildrye cultivar that provides winter livestock forage. It shows a dramatic increase in seedling establishment over other cultivars.

As competition for water supplies increases, FRRL scientists are developing pasture and turfgrasses better adapted to reduced irrigation. For instance, the meadow bromegrass cultivar Cache begins growth in early spring and stays green and succulent longer than tall fescue and orchardgrass. It was recently released for use on irrigated and semi-irrigated pastures. Cache provides livestock producers with increased total dry matter production and seed yield under limited irrigation.

Closer to Home

Other FRRL plant releases were developed from native plant materials collected in the western United States. Germplasm used to create the slender wheatgrass FirstStrike, which can rapidly establish itself on military training grounds, was obtained from several sites in Colorado and Wyoming. Compared to older releases, it has better persistence and seedling vigor under extremely dry conditions.

PEGGY GREB (D1669-1)

In Blue Creek, Utah, geneticist Kevin Jensen examines Snake River wheatgrass in a nursery plot used to identify plants with good persistence, biomass, and seed production. Such traits can help this native plant compete with invasive annual weeds, like cheatgrass.

PEGGY GREB (D1675-1)

Scientists at the Forage and Range Research Laboratory in Logan, Utah, have developed Hycrest II crested wheatgrass. This new drought-tolerant cultivar competes with annual weeds when seeded on rangelands after wildfires, soil erosion, and other disturbances.

Indian ricegrass is widely distributed west of the Mississippi River, and FRRL scientists used several Colorado accessions to develop White River Indian ricegrass. This cultivar can establish itself more readily than other ricegrass varieties and could be an excellent candidate for revegetating land where oil and gas have been mined.

Discovery Snake River wheatgrass, Continental Great Basin wildrye, and Recovery western wheatgrass also become established more easily than other native grasses, help burned lands recover from wildfire, and limit the spread of invasive weeds. Like Secar, another Snake River wheatgrass, Discovery could be used as a surrogate for bluebunch wheatgrass in rangeland seedings.

Last but not least are legumes that can help fix nitrogen in the soils of nitrogen-challenged rangelands. NBR-1 Germplasm Basalt Milkvetch and Don falcate alfalfa are two legumes that have been developed to revegetate western rangelands. Neither is commercially available yet, however.

The nonnative and native grasses and legumes released by FRRL provide land managers and growers with products for diverse, sustainable agriculture.—By **Ann Perry,** ARS.

This research is part of Pasture, Forage, and Range Land Systems (#215) and Plant Genetic Resources, Genomics, and Genetic Improvement (#301), two ARS national programs described at www.nps.ars.usda.gov.

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Fungal Fumes Clear Out Crop Pests

PEGGY GREB (K11933-1)

A codling moth larva crawls out of an apple it infested.

Isolated from the bark of a Honduran cinnamon tree 12 years ago by Montana State University professor Gary A. Strobel, the fungus *Muscodor albus* today continues to impress with its potential as a biobased fumigant.

Indeed, in studies at laboratories in Aberdeen, Idaho; Wapato, Washington; and Parlier, California, ARS scientists have reported success in pitting *Muscodor* against some top agricultural foes: *Tilletia* fungi that cause bunt diseases of wheat; potato tuber moths and apple codling moths; and the gray mold fungus *Botrytis cinerea,* which attacks grapes.

Although the scientists—Blair J. Goates, Lawrence A. Lacey, and Joseph L. Smilanick—are conducting separate investigations of *Muscodor,* they share a common goal. They all seek to determine whether a cocktail of natural compounds emitted by the fungus could replace or diminish use of synthetic pesticides. *Muscodor's* blend of volatile organic compounds (VOCs) naturally kills or inhibits fungal and bacterial pathogens, parasitic nematodes, and some insect pests. Neither *Muscodor* (federally registered by AgraQuest, Inc. of Davis, California, in 2005) nor its fumes harm humans or other mammals, and it leaves behind little or no residue on treated crops or in the environment.

Safeguarding Seedbeds

In May 2009, Goates and Julien Mercier, formerly with AgraQuest, began the third of a 3-year field study evaluating *Muscodor's* ability to control common bunt disease caused by the fungus *T. tritici,* which harms wheat by reducing the yield and quality of its grains, often imparting a foul, fishy odor to them.

Chemical fungicide seed treatments have kept common bunt outbreaks to a minimum, but alternative controls are nonetheless worth exploring should, for example, the chemical lose its effectiveness or be discontinued.

"We've become reliant on chemical seed treatments to control the disease," says Goates, a plant pathologist in ARS's Small Grains and Potato Germplasm Research Unit, in Aberdeen. "Without them, growers in many areas of the United States face the potential for significant yield losses." Such dependence underscores the need for alternatives. Organic wheat growers would benefit too, because they can't use synthetic pesticides and have limited means of fighting the disease.

In lab tests, *Muscodor* VOC's were found to kill 100 percent of *Tilletia* spores. In field trials conducted since 2006, treating seed or soil with a ground-rye-grain formulation of *Muscodor* completely prevented common bunt under moderate disease conditions.

"The dry formulation resembles granola with white frosting," Goates says. Adding water causes that frosting—in actuality, a twisted mass of *Muscodor* fungal fibers called "mycelia"—to begin growing and emit the VOCs, which in turn, fumigate the seed and surrounding soil where *Tilletia* spores lay waiting to germinate and infect plants.

Results from 2009 tests, conducted in naturally infested soils, are pending.

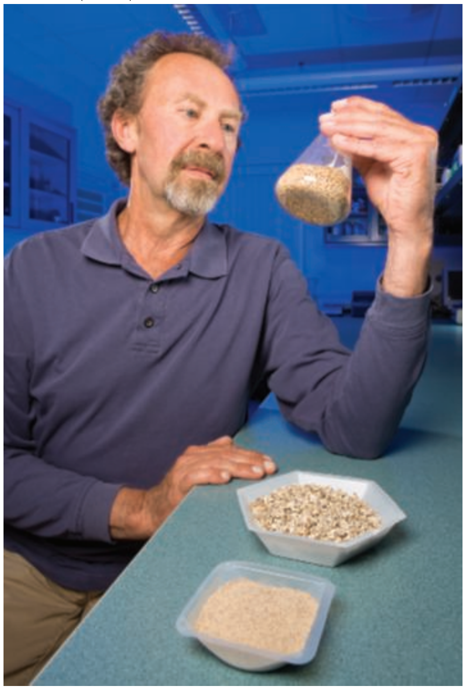
Pest-Proofing Stored Spuds

In Wapato, Lacey and colleagues have pitted *Muscodor* against the potato tuber moth, *Phthorimaea operculella*. In its larval stage, the pest feeds on the crop plant's leaves and tubers, tunneling deep inside the tubers until it's time to emerge and spin a cocoon elsewhere.

Some of the broad-spectrum pesticides growers use to keep the pest at bay cannot be applied within 2 weeks of harvest. That's often enough time for surviving moths to lay their eggs on the tubers before they're harvested and trucked off for storage or sale.

Fumigating the tubers with *Muscodor* during storage could offer a safe, biobased way to finish off those survivors, says Lacey, an entomologist with ARS's Yakima Agricultural Research Laboratory, in Wapato. In fumigation-chamber tests there, 85 to 91 percent of adult moths died when exposed to *Muscodor* fumes, and

PEGGY GREB (D1663-1)



Blair Goates, plant pathologist, examines wheat seed after applying a formulation of the biocontrol fungus *Muscodor albus,* shown in the foreground.

Muscodor's compounds killed 100 percent of *Tilletia* spores in lab tests.

JOSEPH SMILANICK (D1666-1)

Gray mold, *Botrytis cinerea*, on grapes.

between 62 and 73 percent of larvae died or failed to pupate.

In a different study, *Muscodor* overcame the codling moth, *Cydia pomonella*. In its larval stage, the insect bores into apples to feed. In storage tests, a 14-day exposure killed 100 percent of the moths in their overwintering stage—cocooned larvae—when they are the most difficult to control.

"Though our *Muscodor* evaluations have been conducted in laboratory conditions, I am very encouraged by the results," says Lacey, who's collaborated with David R. Horton, Dana C. Jones, Heather L. Headrick, and Lisa Neven—all with ARS.

Most recently, they've been testing *Muscodor's* effectiveness in biofumigating sealed cartons of apples stored at various temperatures. "We've seen no effect on their color and firmness so far," Lacey reports.

Botrytis: Friend—and Foe—to Grape Growers

For those who love grapes, *Botrytis* is both hero and arch-enemy. Some vintners treasure *B. cinerea* because it causes winegrapes to sweeten to perfection, creating memorable dessert wines that have earned this fungus the accolade "noble rot."

But to growers of fresh-market grapes—the kind you buy in bunches to eat out of hand—the microbe is the big-time badguy cause of gray mold.

For organic growers, *Botrytis* is especially troublesome because these producers can't use the typical treatment, sulfur dioxide, to quell it. That's why *Muscodor* studies—by plant pathologist Smilanick and visiting scientist Franka M. Gabler, both at the ARS San Joaquin Valley Agricultural Sciences Center near Parlier, along with Mercier, Jorge J. Jiménez from AgraQuest, and Robert Fassel from Visalia-based PACE International LLC—should benefit conventional and organic growers alike.

For experiments with Thompson Seedless grapes, the researchers placed tea bags filled with *Muscodor* in either of two common types of fresh-grape packaging: vented polystyrene bags or hinged-lid "clamshell" boxes. *Muscodor* reduced the natural incidence of *Botrytis*-infected grapes by up to 85 percent. Factors affecting the infection rate included the concentration of the fumigant, the number of days that had elapsed since the harvested grapes were first exposed to the mold—without prior *Muscodor* protection—and the temperature of the grapes (the fruit, harvested from vineyards that sometimes exceed 100˚F, must be cooled).

PEGGY GREB (D1665-1)

Plant pathologist Joe Smilanick places a clamshell box full of table grapes inside an ozone gas chamber. The "tea bags" inside the boxes contain the biocontrol fungus *Muscodor albus*.

In a test designed with conventional growers in mind, Smilanick, Gabler, Jiménez, and Mercier tried pairing *Muscodor* with sulfur dioxide. "As expected, sulfur dioxide killed a lot of the *Muscodor*," Smilanick reports. "So we tried using *Muscodor* with ozone instead."

The researchers fumigated Autumn Seedless and Thompson Seedless grapes for 1 hour with 5,000 parts per million of ozone and then stored the grapes with the *Muscodor* tea bags for 1 month.

"Even though it wasn't as effective as the standard sulfur dioxide treatment," notes Smilanick, "the ozone-*Muscodor* combination controlled *Botrytis* significantly."

ARS and the California Table Grape Commission funded the research.

If developed commercially, *Muscodor* could offer a powerful new tool for protecting a host of valuable crops and ensuring their quality.—By **Jan Suszkiw** and **Marcia Wood,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301), Plant Diseases (#303), Crop Protection and Quarantine (#304), and Quality and Utilization of Agricultural Products (#306), four ARS national programs described at www.nps.ars.usda.gov.

To reach scientists featured in this article, contact Jan Suszkiw or Marcia Wood, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1630 [Suszkiw], (301) 504-1662 [Wood], jan.suszkiw@ars.usda.gov, marcia.wood@ars.usda.gov. ✷

Chicken House Attics Can Be Tapped To Warm Broilers

Chickens like to stay warm, but insulating, ventilating, and heating their houses can be expensive, especially when fuel prices are high. Fortunately, new technology developed by scientists at the ARS Poultry Research Unit in Mississippi State, Mississippi, and colleagues at Mississippi State University (MSU) could help reduce those costs.

"Energy costs are far and away the largest financial inputs for producers," says ARS agricultural engineer Joseph Purswell, who led the study. "Reducing energy costs means increasing profitability."

Most broiler houses have attics, and the scientists found the air that gathers there can be as much as 20˚F warmer than the air outside. The attic air is at least 5˚F warmer about 70 percent of the time.

Purswell worked with MSU professor Berry Lott, now retired, to develop a ventilation system that uses ceiling inlets to redistribute solar-heated attic air, as opposed to bringing in cooler, outside air. Starting in 2006, Purswell and Lott gathered data from a Mississippi chicken producer who installed several broiler houses based on their design.

The scientists concluded that circulating the warmer attic air within the chicken houses reduced the demand for heating fuel by about 20 to 25 percent. In one study in mild weather conditions, the technology reduced fuel use by 35 percent.

Similar technology has been applied to swine and layer facilities, but this is the first research to examine whether the technology works with broiler houses, which have a significantly different construction.

Commercial interest in the technology has increased with rising fuel prices over the past 3 years, Purswell says. "Now producers throughout the broiler belt are requesting information on how to take advantage of this technology."

The ventilation system has benefits beyond reducing fuel use. Attic ventilation also reduces moisture and ammonia within the houses, which helps improve air quality.—By **Laura McGinnis**, formerly with ARS.

Joseph L. Purswell is in the USDA-ARS Poultry Research Unit, 606 Spring St., Mississippi State, MS 39762; (662) 320-7480, joseph.purswell@ars.usda.gov. ✷

Balancing Water Content and Temperature To Manage Antibiotic Breakdown in Manure

Antibiotics are commonly administered to livestock and pets in the United States to control disease. As in humans, the drugs are often only partially absorbed by the digestive tract, and the remainder is excreted with its pharmaceutical activity intact.

Antibiotic use can create the potential for an increase in antimicrobial resistance, but the mechanisms for development, transmission, and persistence of resistance genes or resistant bacteria are unclear. The mechanisms seem to be unique to the bacterium, the antibiotic and its use, and the environment (gut flora, water, or soil, for example).

Since confined livestock and poultry in the United States generate about 63.8 million tons of manure every year, agricultural producers and public health officials are eager to find ways to facilitate the breakdown of antibiotics in manure. At the Contaminant Fate and Transport Unit in Riverside, California, research leader Scott Yates is investigating the degradation of oxytetracycline (OTC)—one of most common tetracyclines administered to animals—in cattle manure.

In controlled laboratory conditions, Yates found that OTC degraded faster as temperature and moisture content of the manure increased. But he observed that OTC breakdown slowed as water-saturation levels neared 100 percent. He concluded that this slowdown resulted from insufficient oxygen. This laboratory-based research may be useful in designing studies that evaluate the potential effects of lagoons, holding ponds, and manure pits on bacteria and on antimicrobial resistance.

OTC degrades faster as heat and moisture rise.

Yates also found that OTC breaks down more quickly in manure than in soil. Compared to soil, manure has higher levels of organic material and moisture, which support the microorganisms that break down this pharmaceutical.

Results from this study can help livestock producers maximize the breakdown of organic materials and antibiotics that may be in manure by designing storage environments with optimum temperatures and moisture levels. For instance, producers in regions that receive ample sunlight, like Texas and southern California, could use the sunlight to heat the manure—a free, energy-efficient, and ecofriendly way to enhance OTC degradation.—By **Ann Perry,** ARS.

Scott R. Yates is in the Contaminant Fate and Transport Unit, USDA-ARS Salinity Laboratory, 450 W. Big Springs Rd., Riverside, CA 92501; (951) 369-4803, scott.yates@ars.usda.gov. ✷

Why a North American Tree Is Invasive in Europe

Black cherry trees are native to the United States, but they now also thrive in Europe, where they are considered an invasive species. In the United States, damping-off disease, which is caused by the soil pathogen *Pythium,* keeps black cherry trees in check. Researchers collected soil randomly around black cherry trees in more than 20 forests throughout their range in the United States and nearly 20 forests throughout Germany, France, Belgium, and The Netherlands. They then tested the virulence of *Pythium* isolates from each sample and used DNA sequencing to identify each isolate.

They found that some nonaggressive *Pythium* types were common in both ranges, but aggressive types were found only among samples obtained in the United States. Additional research indicates that the density and distribution of black cherry trees is significantly greater in European forests than in U.S. forests.

These combined findings suggest that black cherry trees in Europe are invasive partly because these new populations have escaped virulent *Pythium* species. *Kurt O. Reinhart, USDA-ARS Livestock and Range Research Laboratory, Miles City, MT 59301; (406) 874-8211, kurt.reinhart@ars.usda.gov.*

Catnip Compound Curbs Asian Lady Beetles

At certain times of the year, the multicolored Asian lady beetle, *Harmonia axyridis,* comes inside—sometimes in large swarms—to escape the cold. It's an unwelcome guest because when it feels threatened, it releases a nontoxic yellow liquid that smells foul and produces stains. But in one study, researchers found that almost all adult male and female lady beetles turned away or otherwise tried to avoid the catnip compound nepetalactone—a substance that also shows promise for repelling some cockroaches, flies, termites, and mosquitoes.

These findings could lead to a combined "push-pull" control method, which would use repellents to discourage lady beetles from entering buildings and traps to lure and capture the insects so that they can be released elsewhere. This would allow humans to continue to benefit from the beetle's efficient predation of aphids, scales, and other soft-bodied arthropods that damage plants. *Eric W. Riddick, Biological Control of Pests Research Unit, Stoneville, MS 38776-0067; (662) 686-3646, eric.riddick@ars.usda.gov. Kamal R. Chauhan, Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD 20705; (301) 504-5166, kamal.chauhan@ars.usda.gov.*

SCOTT BAUER (K7033-14)

The Asian lady beetle, *Harmonia axyridis,* is repelled by the catnip compound nepetalactone.

Developing Attractants, Repellents for a Cattle Pest

The stable fly can make cattle miserable, and producers have had only limited success in using traditional insecticides against the pest. Now researchers are identifying aromatic compounds that attract and repel stable flies and have used two compounds found in catnip to develop a control strategy.

In lab tests, the two compounds—ZE-nepetalactone and EZ-nepetalactone—discourage even starved stable flies from biting cattle and feeding on their blood, providing effective protection more than 98 percent of the time. The same compounds have a 95-percent success rate in discouraging female stable flies from laying their eggs. In addition, carbon dioxide and some compounds in manure and bacteria elicit antenna responses from stable flies that are similar to the flies' response to pheromones, which suggests that these compounds might be used as attractants for pest management.

These findings are important steps in developing biobased control tools and improving sustainable stable fly management. *Junwei Zhu, USDA-ARS Agroecosystem Management Research Unit, Lincoln, NE 68583-0938; (402) 472-7525, jerry.zhu@ars.usda.gov.*

Water Hardness Plays a Role in Removing Bacteria from Chicken Skin

Water used in commercial poultry-processing facilities can play a major role in the quality of the meat produced. Researchers have found that soft water is more effective than hard water in removing bacteria from broiler chicken skin. Hard water has higher concentrations of dissolved minerals like calcium and magnesium, and water is softened by removing these minerals.

Scientists compared how well very hard, moderately hard, and soft water rinsed away different bacteria—including *Campylobacter, Staphylococcus,* and *Pseudomonas*—from the skin of broiler chicken carcasses. They found that soft water removed up to 37 percent more bacteria than the other two water types. The effectiveness of sanitization procedures to remove microorganisms from carcasses during processing is affected by several water-quality variables, including pH, ammonia concentration, microbial contamination levels, and hardness.

These findings suggest that poultry processors might want to more closely monitor water hardness and its impact on carcass processing. *Arthur Hinton and Ronald Holser, USDA-ARS Richard B. Russell Agricultural Research Center, Athens GA 30605; (706) 546-3621 [Hinton], (706) 546-3361 [Holser], arthur.hinton@ars.usda.gov, ronald.holser@ars.usda.gov.*

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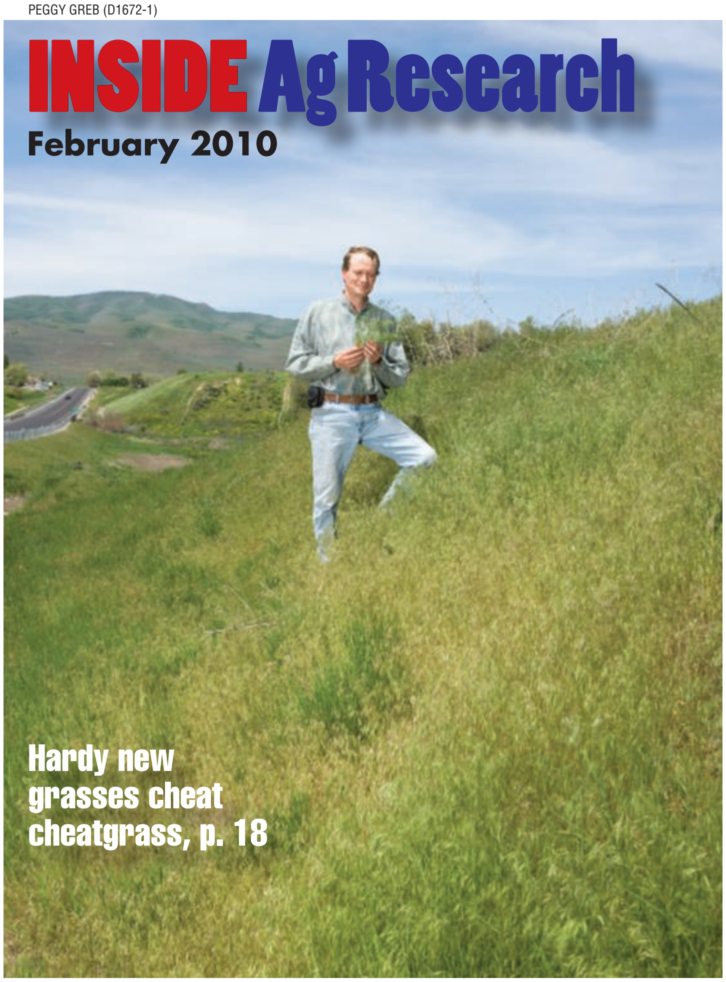

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