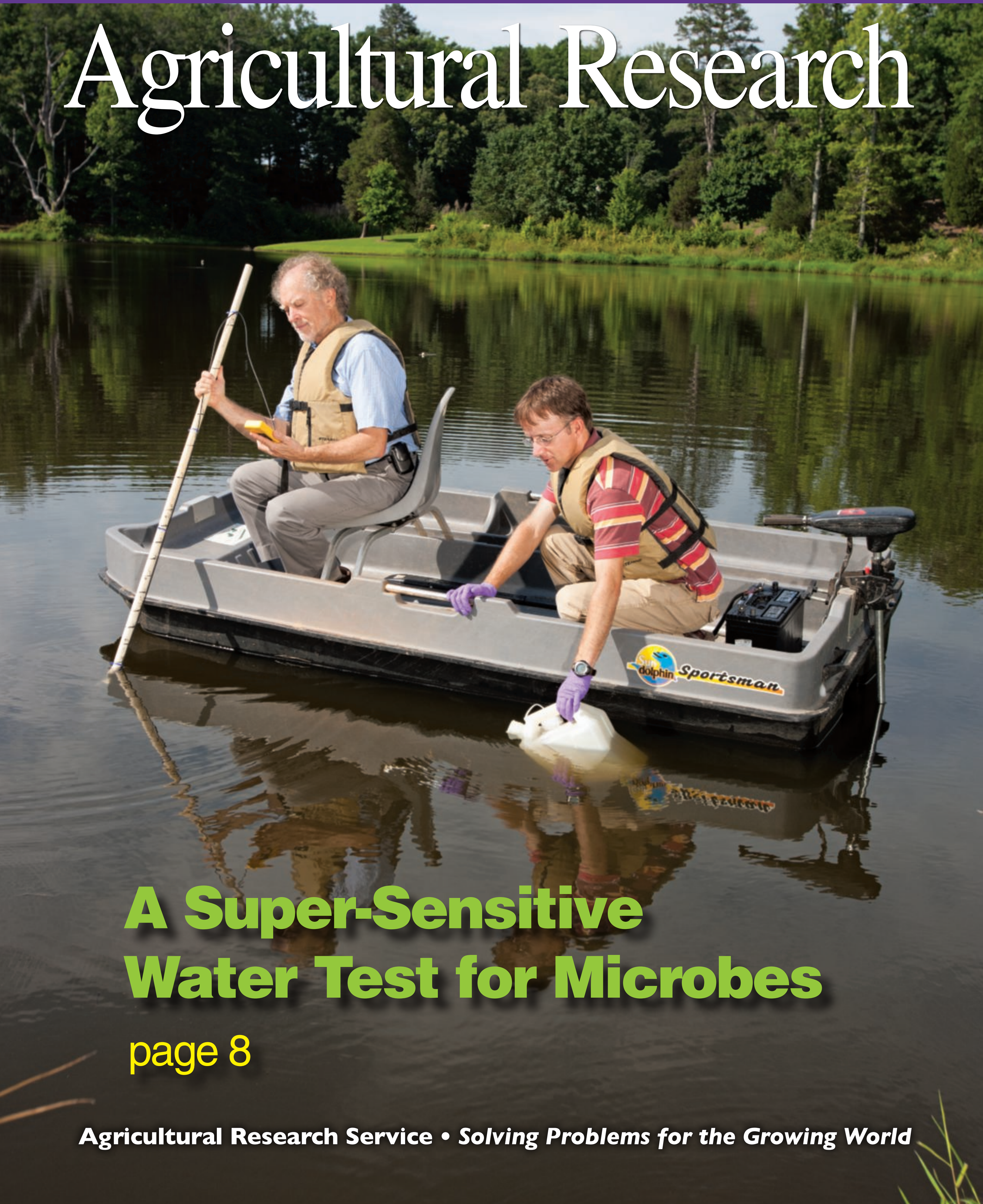
U.S. Department of Agriculture Agricultural Research Service February 2011

Agricultural Research



A Super-Sensitive Water Test for Microbes

page 8

Agricultural Research Service • *Solving Problems for the Growing World*

At the Agricultural Research Service, Bioenergy Is Up and Running

Henry Ford didn't just make Fords—he was also a farmer who regularly received mailings from the U.S. Department of Agriculture (USDA). So it's not surprising that the inscription over the entrance to a Ford administrative building in Dearborn, Michigan, read, "Industrious application of inventive genius to the natural resources of the earth is the groundwork of prosperous civilization."

Now scientists at the Agricultural Research Service (ARS)—and their colleagues in other federal and state agencies, universities, and public and private sector groups—are directing all their inventive genius toward developing the best feedstocks for biofuel production and identifying how they can be sustainably grown. Developing new sources of bioenergy is one of USDA's priorities.

Currently, 78 ARS projects across the country are looking at biofuel production from every possible angle, and the number continues to grow. We're examining switchgrass DNA to see if we can find the genes that regulate traits like disease tolerance or drought resistance, and we'll use that information to find how the best varieties can be managed on farms. This will help growers and biorefiners use the most cost-effective and environmentally sustainable practices for biofuel production, even as they continue to produce the food Americans need.

We're also tracking the types of pathogens that can infect grain ethanol facilities and lower production—and profits.

We're looking at a range of old and new feedstocks for biofuels—such as canola, sugarcane, camelina, *Cuphea,* and sorghum—to assess their potential for cost-effective and sustainable bioenergy-crop production. In Iowa's corn country, we've studied how much corn stover can be harvested for the production of biofuels without increasing soil erosion or compromising soil quality.

Meanwhile, other ARS scientists have found ways to improve dried distiller's grains—a byproduct of grain ethanol production—to supplement animal feed, so that expanding biofuel production doesn't lead to shortages of feed supplements for livestock.

In Pennsylvania, ARS technology has enabled a new commercial undertaking for producing fuel ethanol from winter barley, which is giving farmers along the eastern seaboard a profitable off-season crop that won't compete with food production and that protects soils from eroding into the Chesapeake Bay during winter. On the other side of the country, in the Pacific Northwest, recent studies have indicated that even though switchgrass hails from the East, it might produce yields that are just as good—or maybe even better—in the West (see article, page 4). And as a result of exemplary teamwork between ARS scientists, state and university agronomists, and USDA's Natural Resources Conservation Service, the Colville Confederated Tribes in Washington State might soon be able to grow enough canola on their lands to make biodiesel for fueling their fleet of school buses and logging trucks (see *Agricultural Research,* October 2010).

In February 2010, President Barack Obama outlined a series of steps his administration is taking to enhance American energy independence and build a foundation for a new, clean-energy economy. These steps included a new federal strategy for meeting the country's biofuel targets—and USDA efforts are crucial to the success of this strategy.

Agencies throughout USDA, including ARS, have been tasked with accelerating the commercial establishment of advanced biofuels. ARS is focused on finding ways to advance sustainable production and management of existing agricultural and forest systems over a range of settings across the country.

Given our history and our expertise in working with biofuels, it's not surprising that ARS is working with the USDA Forest Service (FS) to lead five newly established USDA Regional Biomass Research Centers. This USDA-led effort will help ensure that dependable supplies of needed feedstocks are available for production of advanced biofuels to meet legislated goals and market demand. Just as important, the plan sets out to include as many rural areas across the country as possible, so that the economic benefits of biofuel production are as widespread as possible.

The research centers are designed as strategic, coordinated networks of existing ARS and FS scientists and facilities linked not by new buildings or single locations, but by existing and new relationships. The centers will provide the critical mass needed to develop high-performance teams that help guide biomass research across the government.

ARS and FS scientists will team up through the Southeastern Regional Center to work on production of herbaceous, forest, and agroforestry feedstock systems. Work at the Central-East Regional Center will focus on perennial grass biomass systems, while work at the Northern-East Regional Center will target woody biomass and forest biomass systems. Scientists at the Western Regional Center will mainly study new energy-crop systems, and the Northwestern Regional Center researchers will focus on oilseed, forest biomass, and crop residue systems.

For a while, Ford tried producing fuel from Danish potatoes. We know that we'll need a mix of crops and technologies to meet our bioenergy goals, and maybe potatoes won't make that final cut. But even if they don't, we'll still use the leftover oil from making French fries to brew up some biodiesel for the road.

Robert Fireovid
ARS National Program Leader
Bioenergy
Beltsville, Maryland

Jeffrey Steiner
ARS National Program Leader
Biomass Production Systems
Beltsville, Maryland

February 2011
Vol. 59, No. 2
ISSN 0002-161X

Agricultural Research

Solving Problems for the Growing World

Agricultural Research is published 10 times a year by the Agricultural Research Service, U.S. Department of Agriculture (USDA). The Secretary of Agriculture has determined that this periodical is necessary in the transaction of public business required by law.

Tom Vilsack, Secretary
U.S. Department of Agriculture

Catherine E. Woteki, Under Secretary
Research, Education, and Economics

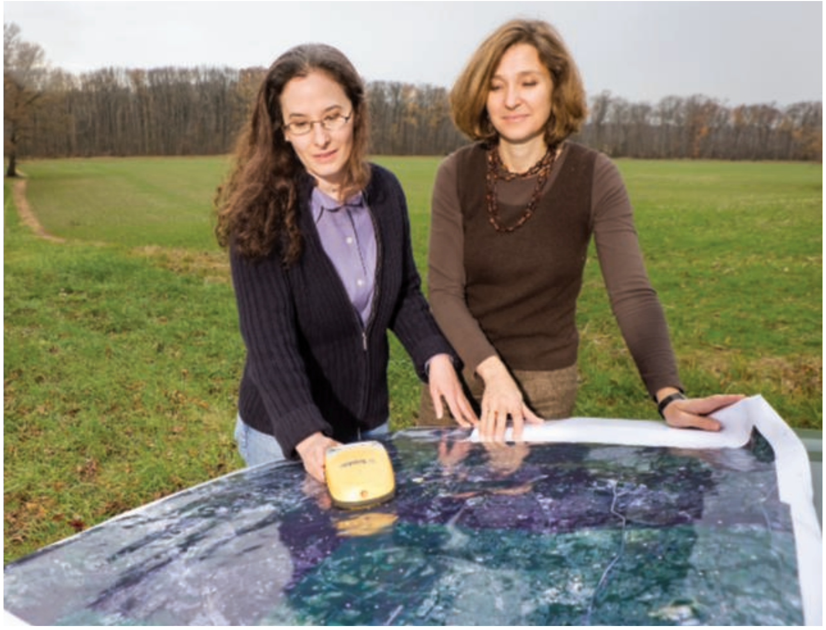
Edward B. Knipling, Administrator
Agricultural Research Service

Sandy Miller Hays, Director
Information Staff

Editor: Robert Sowers	(301) 504-1651
Associate Editor: Sue Kendall	(301) 504-1623
Art Director: BA Allen	(301) 504-1669
Photo Editor: Anita Daniels	(301) 504-1609
Staff Photographers:	
Peggy Greb	(301) 504-1620
Stephen Ausmus	(301) 504-1607

Paid subscriptions are available from the U.S. Government Printing Office (Superintendent of Documents). See back cover for ordering information. Complimentary 1-year subscriptions are available directly from ARS to public libraries, schools, USDA employees, and the news media. Call (301) 504-1638 or e-mail armag@ars.usda.gov.

STEPHEN AUSMUS (D2088-13)



Scientists study a satellite image in efforts to promote the Chesapeake Bay's health. Story begins on page 10.

4 Prospecting for Pacific Northwest Biofuel Crops

6 Bioenergy Options in the Pacific Northwest

8 A Better Way To Track *Salmonella* and *E.coli* in Waterways

9 Using Genetics To Build a Better Tomato

10 Federal Forests Still Protecting Chesapeake Bay After 100 Years

12 Phytosanitizing Hawaiian Fruit: A Technology Transfer Success Story

15 Tangerine Tomatoes Top Reds in Preliminary Lycopene Study

16 "Fire Gel" Protects Beneficial Nematodes From Sun

19 Examining Climate Change Effects on Wheat

20 Studying Streambanks Reveals Their Weaknesses and Strengths

22 Agro/Environmental Data at Your Fingertips

23 Locations Featured in This Magazine Issue

New!

Cover: It can take just 100 cells of *Salmonella* or *E. coli* to make you sick. Public waterways are routinely tested for signs that these organisms may be present, but current testing methods can't always detect the pathogens at very low levels. Agricultural Research Service scientists in Watkinsville, Georgia, have combined several laboratory techniques into a new method that can spot the microbes at lower levels than ever before. See story on page 8. Photo by Peggy Greb. (D2071-2)

Prospecting for Pacific Northwest Biofuel Crops

PEGGY GREB (D2065-1)

Microbiologist Hal Collins reads a rain gauge in a study to determine switchgrass water-use efficiency.

Since 2003, Agricultural Research Service microbiologist Hal Collins and agronomist Rick Boydston have been working with colleagues at Washington State University to figure out how an assortment of crops could be introduced into existing high-value irrigated vegetable rotations. Their study—the first of its kind in the state of Washington—included safflower, camelina, soybeans, mustard, canola, wheat, corn, and switchgrass. As a result, there's now some key information on biofuel crop production for farmers in the region.

"These first trials were initial steps," says Collins, who works at the ARS Vegetable and Forage Crops Research Laboratory in Prosser, Washington. "We wanted to test a number of bioenergy crops to see if their production in our region was feasible and if they could provide high enough returns to growers by competing with other crops."

Cruising on Canola

Canola is a relatively new crop to Washington growers, since few varieties have been specifically developed for environments with cool winters and hot summers. It is not affected by Russian wheat aphid, Hessian fly, or wheat diseases such as take-all, which is caused by the fungus *Gaeumannomyces graminis,* and eyespot, caused by the fungus *Pseudocerospoelle hepitricoides*. So when wheat is planted in fields where canola was previously cultivated, the incidence of these pathogens drops.

PEGGY GREB (D2066-1)

Agronomist Rick Boydston takes height measurements on switchgrass.

"We're finding that canola can be grown in a lot of different environments in the Pacific Northwest," Collins says. In a study of four different varieties of canola that were cultivated at three sites, the scientists found that the average seed yield was around 3,000 pounds per acre. This would yield around 1,200 pounds of seed oil per acre, which could provide the raw oil to make 160 gallons of biodiesel. A farmer with 1,000 acres and an onsite crusher and biodiesel facility would need 50 to 70 acres to grow enough canola to produce the fuel needed to run on-farm operations.

Winter canola also protects soil from erosion in hilly regions, and the plant's deep root system, sometimes reaching more than 8 feet below the soil, can break through hard subsurface soil layers. This allows the plant to take up nutrients that have leached below the root zone of previous crops, which helps reduce ground-water contamination. The crop also adds organic matter to the soil—another production plus.

Other Oilseed Options

When a 53-foot, 29,000-pound Air Force A-10 Thunderbolt jet successfully—and uneventfully—completed a test flight using a 50-50 blend of camelina-based fuel and regular jet fuel, producers and scientists alike took note.

"Compared to canola seeds, which are 40 percent oil, camelina seeds are 35 percent oil, and seed yields per acre are lower in our growing conditions," notes Collins. Still, in field trials, camelina, a shrublike plant with yellow flowers, produced an average of 2,000 pounds of seeds per acre in 80 days. That translates into 700 pounds of oil—and eventually 93 gallons of fuel—per acre.

Safflower plants have bright, bristly blossoms and seeds that contain between 42 percent and 48 percent oil. Their taproot systems can penetrate as deep as 10 feet in the soil to find water, and the plants produce around 3,000 to 3,500 pounds of seeds per acre. The Prosser scientists used deficit-irrigation strategies that resulted in a water savings of 7 inches and only a small reduction in oilseed yield.

White mustard *(Sinapis alba),* another crop that is fairly new to Washington growers, is also in the mix. The plant performs best with cool winters and hot summers, and its seeds contain about 25 to 30 percent oil. But it is also more drought tolerant than canola—and it could be a very versatile commodity.

"The seeds are crushed for oil, and the mustard meal that remains has high levels of glucosinolate, which acts as a biofumigant," says Boydston, who also works in the Prosser laboratory. "The meal can be used as an organic fertilizer or as a soil fumigant to suppress harmful nematodes and weeds."

Field trials indicate that, depending on the variety of oilseed, 50,000 to 80,000 acres would be needed to support a single 5-million-gallon biodiesel facility. And there could be a ready market for that biodiesel, since some estimates suggest that nearly 1 billion gallons of diesel derived from petroleum are consumed every year in Washington. Although there are 10 companies currently producing and distributing biodiesel in the Pacific Northwest, most of it is produced with waste grease.

Switching to Switchgrass

The Prosser scientists aren't restricting their dealings to oilseed feedstocks for biofuels. Their work suggests that with enough rainfall or irrigation, farmers in the warmer parts of the Pacific Northwest could also grow warm-season grasses, such as switchgrass, for use in cellulosic ethanol production or in gasification plants or other biopower-production facilities.

The team evaluated 11 switchgrass cultivars and found Kanlow to be the most promising cultivar for maximum production under sustainable irrigation strategies in the Pacific Northwest's Columbia Basin. Four years after the team planted the first crop, they measured yields of 14 dry tons per acre, which could translate into around 1,000 gallons of cellulosic ethanol per acre. New switchgrass cultivars will be added to the trials when they become available.

Of course, the economic viability of any of these potential bioenergy crops depends on further development of the bioenergy industry infrastructure in the Pacific Northwest. The location of future biorefineries will be key to cost-effective biofuel production (see story, page 6), as will initial market incentives and support for other aspects of the supply chain.

Collins and Boydston will continue their fieldwork, and they'll also begin performing the economic analyses. "We'll evaluate how the crops fit into high-value vegetable production, find improvements in crop irrigation and fertilization practices, and identify uses for biofuel coproducts," Collins says.

"Biofuels are here to stay in the Pacific Northwest, and farmers are looking for information they can use to produce these crops economically," adds research leader Ashok Alva. "We need to fine-tune management practices so that the growers will be able to make appropriate decisions on incorporating these feedstocks into their current production systems."—By **Ann Perry,** ARS.

This research is part of Crop Protection and Quarantine (#304), Agricultural System Competitiveness and Sustainability (#216), and Bioenergy (#213), three ARS national programs described at www.nps.ars.usda.gov.

To reach the scientists mentioned in this article, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628, ann.perry@ars.usda.gov. ✻

PEGGY GREB (D2069-1)

Technician Rebecca Cochran evaluates oilseeds produced in biofuel field trials. She is working with camelina (under the microscope). Seeds on the table (clockwise from top left) are canola, soybeans, flax, safflower, and mustard.

Bioenergy Options in the Pacific Northwest

Clutching at 6 Million Tons of Straw

Pacific Northwest farmers can make a good profit on their wheat, barley, oats, and grass-seed crops. But when they sell the leftover straw for livestock feed and bedding, they barely break even. Converting that straw to bioenergy could result in added value all the way around—more money for farmers and more renewable energy for consumers.

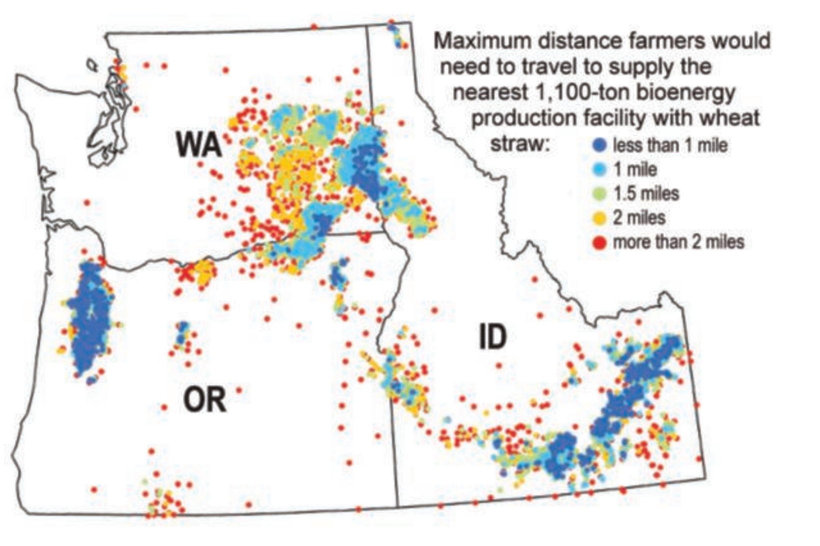
Now, Agricultural Research Service agronomist George Mueller-Warrant, plant physiologist Gary Banowetz, and hydrologist Jerry Whittaker have figured out the best locations in the Pacific Northwest to build facilities to produce bioenergy from straw. Their calculations could help producers and biorefiners minimize straw-transaction costs and maximize returns as bioenergy production ramps up.

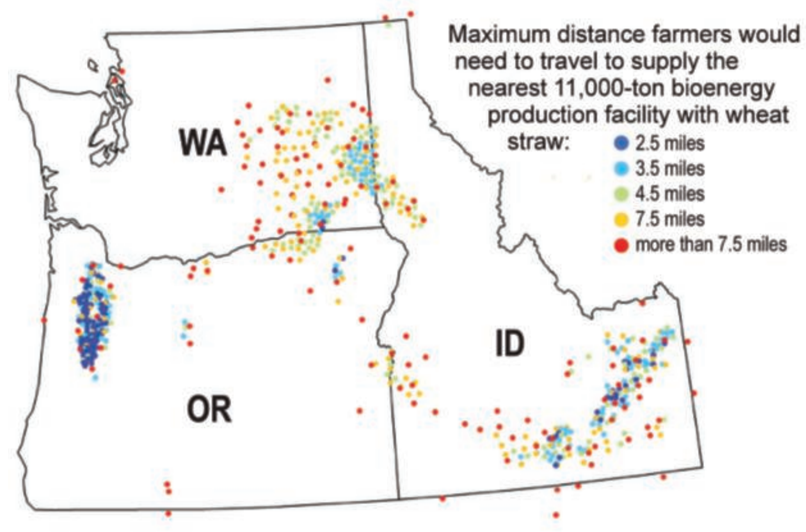
"Straw is bulky and doesn't have nearly the energy content that corn does. So the model for shipping corn grain to a Midwest ethanol bioenergy plant isn't really applicable for much of the Pacific Northwest, where straw density per acre is small," says Banowetz, who works with Mueller-Warrant and Whittaker at the ARS Forage Seed and Cereal Research Unit in Corvallis, Oregon. "And since rainfall patterns are a lot more variable in the Pacific Northwest, our straw yields are variable as well. Since we don't have a uniform biomass yield across the region, it makes sense that different-scale conversion facilities are needed that account for the available straw that can be economically supplied to them from local sources."

"So we needed to figure out where the straw was and where the straw wasn't," Mueller-Warrant says. "Once we knew that, we could begin developing models for locating the conversion facilities."

Taking Inventory

The scientists used a combination of satellite imagery, data from the USDA National Agricultural Statistics Service and the National Land Cover Database, and other information to produce county-by-county straw yields for 2005, 2006, and 2007. After excluding straw residues left on fields to protect the soil from erosion and to help maintain soil quality, they determined that the average annual





An ARS team ran a series of computer models that identified the best locations for building bioenergy plants based on how closely the plants could be located to wheat straw feedstocks needed for ethanol production. The facilities are color coded on each map to indicate the maximum distance the straw would need to be transported to supply the nearest facility. Reducing transport costs is key to farmers' making a profit in this enterprise.

regional straw yield was around 6.2 million tons—enough straw to produce more than 430 million gallons of biofuel.

Then the scientists revised a statistical approach used by community planners and business developers to determine the best locations for stores, hospitals, police stations, and other facilities. They used the revised methodology to calculate how many total biofuel facilities could be supplied by the average annual straw yield—and where to locate the plants so that the costs of transporting low-density straw could be minimized.

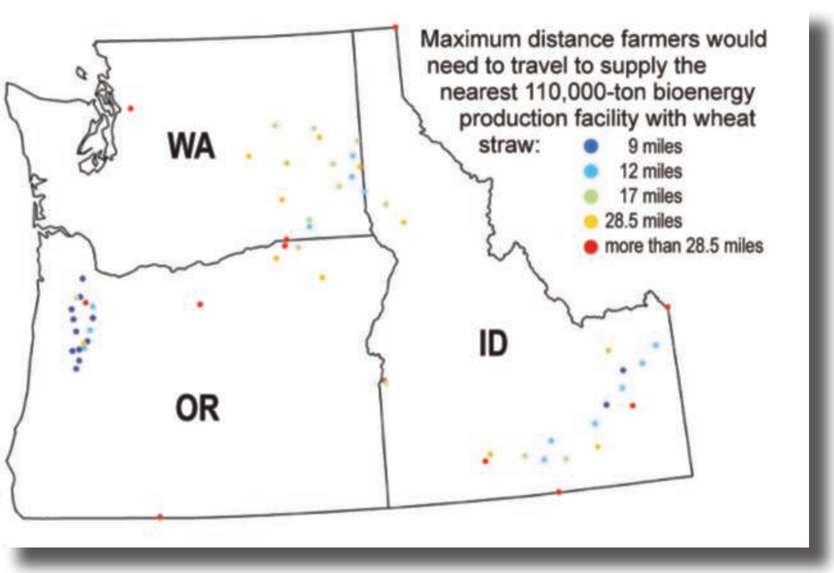
In their studies, they looked at facilities that had three different scales of annual production: Small-scale facilities could handle 1,100 tons of straw, medium-sized facilities could handle 11,000 tons of straw, and large-scale facilities could handle 110,000 tons of straw. Relative to the corn-to-ethanol plants operating in the Midwest, all three sizes represent small-scale facilities.

The model for the small-scale plant was a syngas-powered electrical generator system suitable for a farm-sized facility, a model currently being tested by the Corvallis scientists on a farm in Spokane, Washington. The large-plant model was similar to an Oregon biofuel facility in development for the western part of the state. The model for the medium facility was for either a large-scale syngas production facility or a series of distributed bio-oil production sites with railway access for shipping bio-oil to large, more centrally located refineries that could be supplied with straw from several farms.

Conveniently Located in a Field Near You

Results indicated that the straw in the Pacific Northwest available for producing bioenergy could be allocated to 6,200 small facilities, 660 medium facilities, or 64 large facilities (see maps). The smallest facility could provide enough electricity to serve the needs of 55 people, based on average annual electricity usage in the United States. While this electricity could be returned to the electrical distribution grid for general use, it is most likely that electricity produced from the small facilities would be used on farms to power irrigation pumps, dairy operations, or seed- and grain-cleaning mills.

More than half the plants of all three sizes had enough straw available within a reasonable travel radius. For example, in regions like eastern Washington, where straw production averages around 2 tons per acre, producers would have to travel a median distance of 1.4 miles to supply the small-scale plants. In the Willamette Valley of western Oregon, where annual straw production is about 4 tons per acre, a median travel distance of under 1 mile would supply the same-sized plants. Across the region, producers supplying the largest plants would have to travel a median distance of 13 miles.



The variability in straw distribution would probably mean that only 80 to 90 percent of the total available straw could be used for bioenergy production. While the small plants were distributed more evenly across the Pacific Northwest, the straw supply for these facilities was more variable from year to year. "Farmers are used to variability," Mueller-Warrant observes wryly.

"That's part of the larger risk analysis that will be involved in siting these plants," Banowetz adds. "Even though smaller facilities might have more variability in their biofeedstock supply, they would also require less start-up capital. And an on-farm energy system could help insulate farmers who use a lot of electricity, like dairy farmers or farmers who irrigate, from energy price increases."

"When we evaluate our results, we also need to consider the impact of evolving energy-production technologies," Mueller-Warrant says. "We don't know what will be available 5 to 10 years from now and what will be a factor in the cost-effectiveness of these sites. Maybe the winner will end up being a farm-scale system—or maybe it will be a large-scale bio-oil or bio-gas plant."

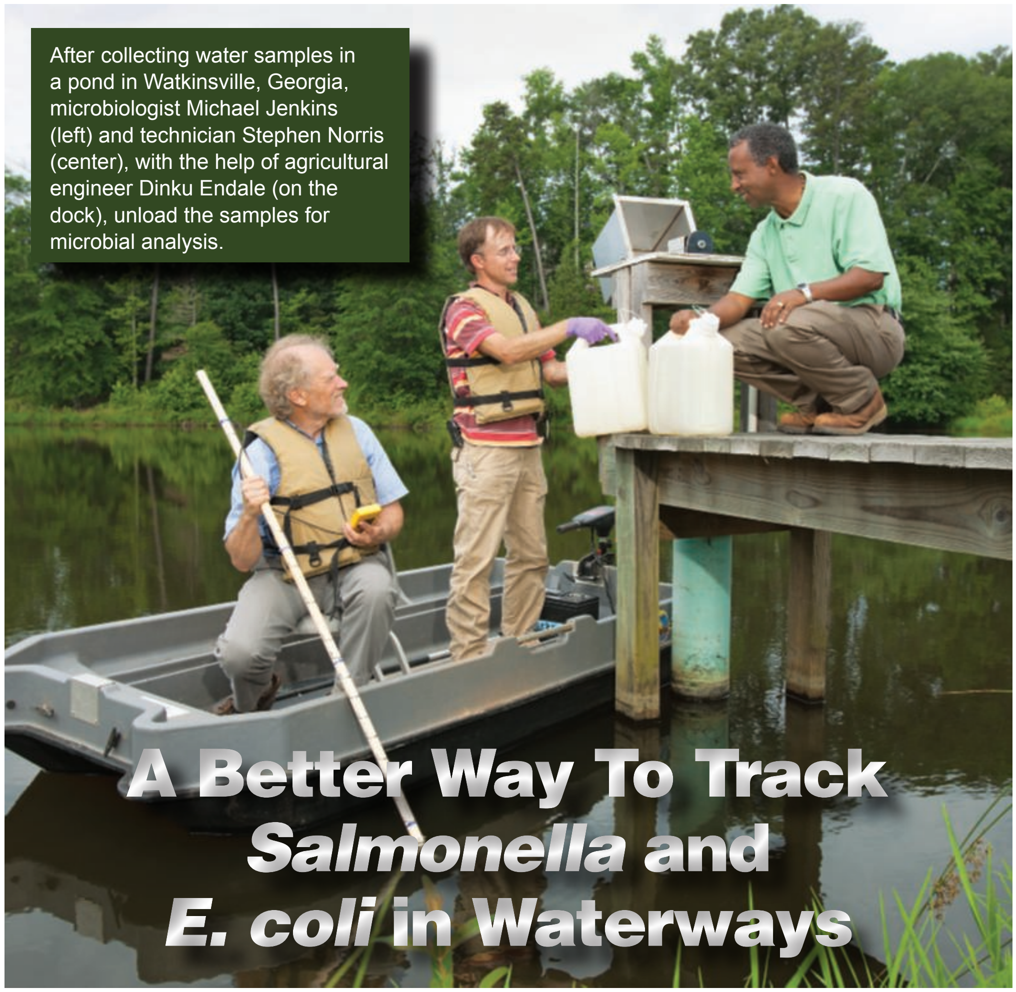
Says Banowetz, "Idaho, Washington, and Oregon all have state mandates to increase their energy production from renewable sources. For instance, by 2020, 20 percent of Oregon's energy will need to be produced using renewable resources—and Oregon doesn't classify hydropower as a renewable source. So these mandates are driving a lot of interest in our work and our findings."—By **Ann Perry,** ARS.

This research supports the USDA priority of developing new sources of bioenergy and is part of Bioenergy (#213) and Agricultural System Competitiveness and Sustainability (#216), two ARS national programs described at www.nps.ars.usda.gov.

To reach the scientists mentioned in this story, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628, ann.perry@ars.usda.gov. ✻

A Better Way To Track *Salmonella* and *E. coli* in Waterways

PEGGY GREB (D2072-1)



After collecting water samples in a pond in Watkinsville, Georgia, microbiologist Michael Jenkins (left) and technician Stephen Norris (center), with the help of agricultural engineer Dinku Endale (on the dock), unload the samples for microbial analysis.

A team of Agricultural Research Service scientists at the J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, Georgia, has come up with a way to detect both *Salmonella* and pathogenic (disease-causing) *E. coli* in waterways at lower levels than any previous method could. Similar methods have been developed to detect pathogenic *E. coli* in meat products, but the team's approach represents a first for waterways.

When health officials test a public beach or a lake for *Salmonella* or *E. coli* O157:H7 as part of a routine inspection, they test for the presence of two types of nonpathogenic bacteria—*Enterococci* and generic *E. coli*—as indicators of the presence of the pathogens. They do this because the pathogens themselves are hard to detect directly at the low levels that can make someone sick: Just 100 cells of *Salmonella* or 10–100 cells of *E. coli* O157:H7 can cause illness.

The bacterial indicators are commonly found in the intestines of warm-blooded animals. But while they are often detected in contaminated waterways, their abundance doesn't guarantee the presence of either pathogen, says Michael Jenkins, a microbiologist at the ARS center. Investigators have detected the indicators in pathogen-free waters and failed to find them in waters with sufficient levels of the pathogens to make someone sick.

Salmonella and *E. coli* outbreaks are often attributed to agricultural operations, so improving the methods for tracking down sources of outbreaks is a major priority. "Our goal is to be able to use the pathogens themselves in assessing the contamination, instead of the indicator organisms," Jenkins says.

Jenkins and his ARS colleagues Dinku Endale and Dwight Fisher combined techniques previously developed to assess water quality and detect pathogens in laboratory settings: a water-filtration technique to concentrate the pathogens; a special medium for growing and measuring the number of pathogenic cells; a biochemical testing process; and PCR (polymerase chain reaction) technology, a molecular identification technique often used to increase or magnify a small sample of DNA.

They collected water samples from different points in a pond at the Watkinsville site, ran them through a special filter, removed the filter contents, and used a centrifuge to spin the filtered contents into a pellet form. They cultured the pellets to ramp up the amount of pathogens found in the original samples. To confirm the presence of the pathogens at the molecular level, they used PCR technology. As a control measure, they ran sterile water through the system and used some water samples spiked with pathogenic *E. coli* and *Salmonella* to test the filtration system.

The results showed that the process is able to detect just a few cells of pathogenic *E. coli* and *Salmonella* in 10-liter water samples, lower levels than any previously detected. The work, published in two papers in the *Journal of Applied Microbiology,* is a significant step toward improving the methods used by federal, state, and local agencies to track down the sources of outbreaks of *Salmonella* and pathogenic *E. coli*. Because the system involves cell cultures, it should lead to developing culture collections that, like a fingerprint database, could be used to identify bacterial strains and sources of future outbreaks.

"The sensitivity of this method will enhance our understanding of the fate and transport of these pathogens in agricultural watersheds, and it should prove helpful in identifying the sources of these pathogens in the environment," Jenkins says.—By **Dennis O'Brien,** ARS.

This research is part of Manure and Byproduct Utilization, an ARS national program (#206) described at www.nps.ars.usda.gov.

Michael Jenkins is with the J. Phil Campbell Sr. Natural Resource Conservation Center, 1420 Experiment Station Rd., Watkinsville, GA 30677; (706) 769-5631, michael.jenkins@ars.usda.gov. *

Using Genetics To Build a Better Tomato

Agricultural Research Service researchers are working to save our tomatoes—or at least some of them.

Tomatoes spend so much time on shelves and in refrigerators that an estimated 20 percent are lost to spoilage, according to the USDA Economic Research Service. Autar Mattoo, an ARS plant physiologist with the Sustainable Agricultural Systems Laboratory in Beltsville, Maryland, is trying to change that. Mattoo is working with Avtar Handa, a professor of horticulture at Purdue University, to enhance tomatoes so that they offer not only better taste and higher nutrient levels, but also a longer shelf life.

Mattoo, Handa, and Savithri Nambeesan, a graduate student working with Handa, recently focused on manipulating a class of nitrogen-based organic compounds known as "polyamines" that act as signals and play a role in the plant's growth, flowering, fruit development, ripening, and other functions. Polyamines have also been linked to the production of lycopene and other nutrients that lower our risk of developing certain cancers and other diseases, making them a prime target for investigation, according to Mattoo.

"We wanted to see if we could increase the levels of polyamines in tomatoes and then investigate their biological effects," Mattoo says.

The researchers introduced a yeast gene, known as "spermidine synthase," into tomato plants specifically to increase production of a single polyamine—spermidine. Spermidine is found in all biological organisms and is one of three polyamines believed to modulate the plant-ripening process.

The results, published in *The Plant Journal,* showed that introducing the gene not only increased spermidine levels and vegetative growth, but also significantly extended the tomato's postharvest shelf life. Shriveling was delayed by up to 3 weeks, and there was a slower rate of decay caused by tomato plant diseases. The tomatoes also had higher levels of the antioxidant lycopene. The study shows for the first time that spermidine has its own effects, independent of the other polyamines, extending shelf life and increasing growth.

STEPHEN AUSMUS (D2089-5)

In a Beltsville, Maryland, greenhouse, plant physiologist Autar Mattoo (center) points out features of a genetically improved tomato line to postdoctoral fellow Vijaya Shukla (left) and biological technician Joseph Sherren.

Polyamines are found in other plants, so the work could assist in efforts designed to extend the postharvest shelf life of other crops.

"We know that in tomato fruit, the signaling machinery continues to function late into the ripening process. By designing genes that would lead to higher levels of polyamines, it should be possible to modulate ripening and influence nutrient levels as well," says Mattoo.

The use of molecular genetics to enhance tomatoes has faced some resistance from consumers and industry. But scientists have used such molecular techniques for years to develop improved varieties of corn, soybeans, and cotton, and Mattoo is confident that in time the approach will become more widely accepted as its benefits are better understood.—By **Dennis O'Brien,** ARS.

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

Autar Mattoo is with the USDA-ARS Sustainable Agricultural Systems Laboratory, 10300 Baltimore Ave., Bldg. 001, Room 119, Beltsville, MD 20705-2350; (301) 504-6622, autar.mattoo@ars.usda.gov. *

Federal Forests Still Protecting Chesapeake Bay After 100 Years

For 100 years, the Henry A. Wallace Beltsville Agricultural Research Center (BARC) in Beltsville, Maryland, has maintained and protected its share of 25,660 acres of green space just 15 miles from the nation's capital.

The expanse of green space, sometimes called the "Green Wedge," owes its existence to the fact that most of it has been in federal hands since before 1940. BARC was the first federal landowner, beginning with about 500 acres in 1910.

A 2009 Executive order on the Chesapeake Bay—calling for increased cooperation between federal, state, and local agencies and organizations—finds BARC once again at the forefront of environmentally and fiscally responsible cooperative land-use decisions affecting this vast open space.

This cooperation began formally in 2006 with the signing of an agreement with three other major landowners—the U.S. Fish and Wildlife Service's Patuxent Research Refuge, the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center, and the U.S. Army's Fort George G. Meade—as well as the Maryland Department of Natural Resources and the nonprofit Center for Chesapeake Communities, officially forming the Baltimore-Washington Partners for Forest Stewardship. That same year, ARS's Beltsville Area Office signed a similar agreement with the Metropolitan Washington Council of Governments.

The Bay's Lungs and Kidneys

Over the years, BARC grew, but ceded about half of its land to other agencies, including the U.S. Departments of State, Treasury, and the Interior, and NASA—leaving BARC with 6,615 acres today. But most of the green space has been left intact—virtually as it was in 1910.

At an experimental watershed in Beltsville, Maryland, ARS scientists measure the movement of agrichemicals from a corn field to the riparian buffer in the background. Agronomist Craig Daughtry (left) operates the water pump while soil scientist Timothy Gish (center) takes field notes and soil scientist Gregory McCarty collects a groundwater sample.

STEPHEN AUSMUS (D2091-12)

The Green Wedge is a national treasure, the largest expanse of continuous deciduous forest remaining between Norfolk, Virginia, and Boston, Massachusetts. It serves as the lungs and kidneys for the Washington, D.C., metropolitan area in the bay's watershed, with vegetation and wetlands that filter out pollutants. BARC streams deliver clean water to the bay. In fact, Upper Beaverdam Creek, on BARC land, sets state standards for clean water. One of the many ways the partnership keeps these waters so clean is by planting trees along the streambanks as buffers.

The partners encourage collaborative solutions to shared challenges by bringing together scientists from the different agencies that share the Green Wedge. For example, Megan Lang, a USDA Forest Service ecologist stationed at BARC, and Molly Brown, a scientist at NASA-Goddard, work together to offer remote-sensing tools to land managers within the Green Wedge.

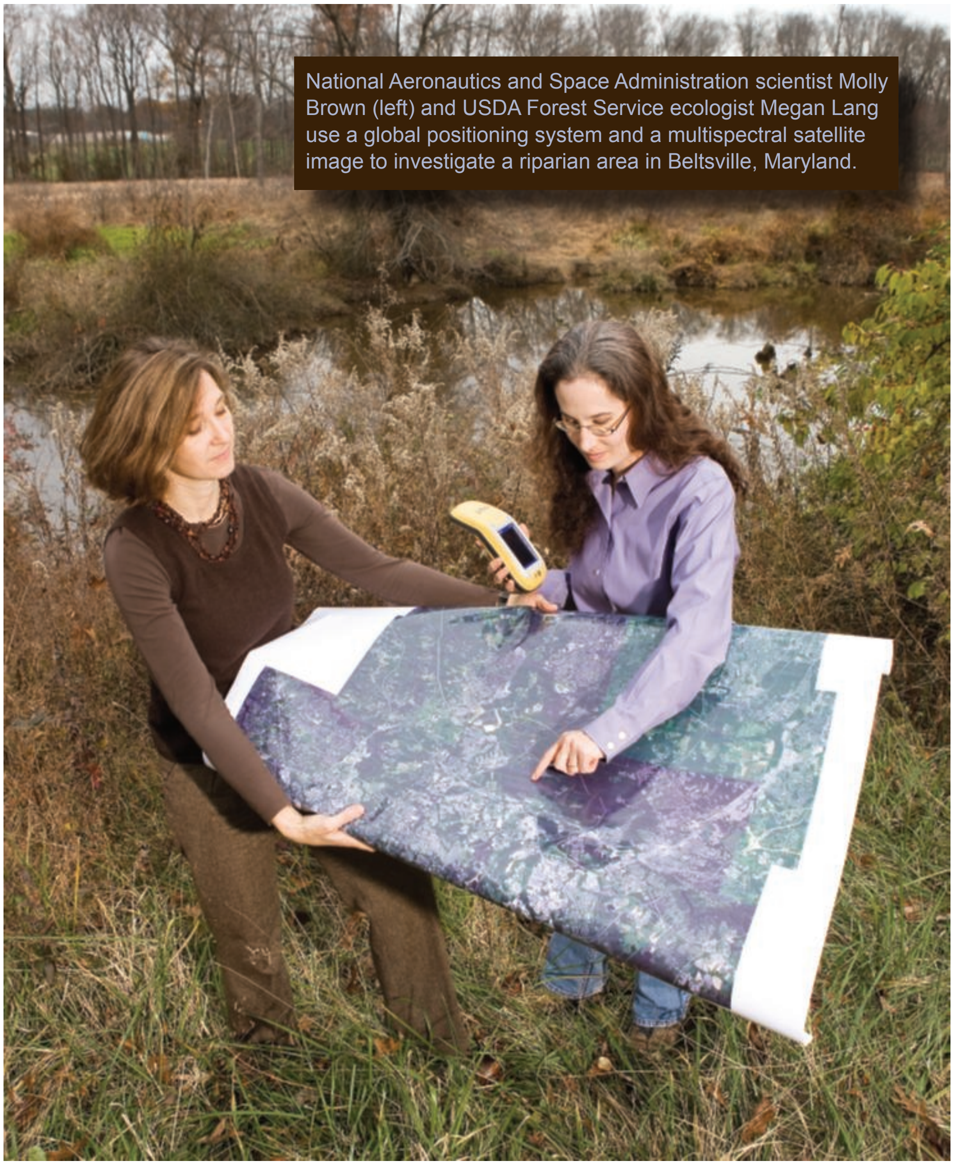
Another example is joint pest-control efforts. A few years ago, Patuxent, Goddard, and three other federal agencies joined BARC in using a biological insecticide, GYPCHEK, to protect oak trees from gypsy moths. The Forest Service developed GYPCHEK, and ARS scientists did research seeking improved efficiency in producing the naturally occurring virus strain that is its active ingredient.

David Prevar, the ARS Beltsville area safety and health manager, says that threats such as gypsy moths "do not respect property lines, so it pays for landowners to work together."

The Green Wedge's Historical Forests

A BARC ecology committee has been protecting the Green Wedge since 1977. Through this committee, scientists worked to have forests on this land designated as research forests to reflect their historical and continuing contributions to protecting wildlife and the Chesapeake Bay. The

STEPHEN AUSMUS (D2087-15)



National Aeronautics and Space Administration scientist Molly Brown (left) and USDA Forest Service ecologist Megan Lang use a global positioning system and a multispectral satellite image to investigate a riparian area in Beltsville, Maryland.

honor also reflects the historic cooperative research done by the Patuxent Research Refuge and ARS scientists for the benefit of wildlife habitat. Patuxent scientists have developed techniques for monitoring wildlife, such as spotted salamanders and other amphibians, on BARC as well as Patuxent lands.

About 1990, BARC switched to sustainable farm-operation practices to reduce pesticide use and erosion losses. These changes were based on the results of BARC research.

In 1996, BARC voluntarily began a nutrient-management plan—5 years before the State of Maryland required this for private farms—to keep nitrogen and phosphorus out of the Chesapeake Bay. Studying an experimental watershed on BARC, ARS soil scientist Greg McCarty determined ways to improve the effectiveness of vegetative riparian buffers to filter out nutrients and pesticides before they reach the bay. Again, BARC scientists developed these practices, through research, to serve as a model for bay-area farmers.

A Green Way To Cap an Old Landfil

From 2003 through 2008, Prevar, working with ARS microbiologist Pat Millner, the U.S. Environmental Protection Agency, and private consultants, designed and conducted a pilot study for an alternative vegetative capping method on part of a 30-acre municipal landfill located at BARC.

The Maryland Department of the Environment has been following this project closely, since there are numerous landfills statewide that would benefit from this alternative closure approach. Vegetative caps for landfills, rather than traditional clay caps, are gaining acceptance from state agencies as a sustainable practice, and EPA sees the BARC project as a potential model. This method of capping is more environmentally sound and economical, and, if accepted by Maryland, would provide the added benefit of creating more than 30 acres of forest canopy and critical habitat when fully implemented.

"As part of the vegetative capping design, Pat has come up with a novel way to reduce methane emissions while preventing rainfall from penetrating into the municipal waste and then leaching into groundwater," Prevar says. "Also, an increase in forest canopy contributes to improving the bay's health by sequestering carbon and filtering runoff."

The Next 100 Years

As though in repayment for the research and stewardship, the lands constantly reveal new surprises, such as globally rare forms of plants and wildlife—including a new bee species, a surprising number of dragonfly species, 141 rare plant species, including two species of orchids, and rare plant communities such as magnolia bogs and pine barrens.

"These natural resources expand our research opportunities and demonstrate the importance of inventorying and preserving important ecological resources beyond our 100th anniversary," Prevar says.

This research supports the USDA priority of responding to climate change.—By **Don Comis,** ARS.

This research is part of Manure and Byproduct Utilization (#206), Water Availability and Watershed Management (#211), Agricultural System Competitiveness and Sustainability (#216), and Crop Protection and Quarantine (#304), four ARS national programs described at www.nps.ars.usda.gov.

David A. Prevar and Patricia D. Millner are with the USDA-ARS Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD 20705; (301) 504-5557 [Prevar], (301) 504-5631 [Millner], david.prevar@ars.usda.gov, pat.millner@ars.usda.gov. *

Phytosanitizing

SUZANNE SANXTER (D2103-1)

As part of the quality analysis of irradiated tropical crops, food technologist Marisa Wall uses high-pressure liquid chromatography to analyze dragon fruit extracts for possible changes in sugar composition due to irradiation.

Papaya, rambutan, longan, dragon fruit, and purple-fleshed sweetpotato are just some of the delicious tropical fruits and vegetables gaining popularity in the continental United States. Chances are these delectable delights, now found in grocery stores and specialty Asian supermarkets all over the country, were grown in Hawaii.

But just 5 years ago, one would have been hard pressed to find these healthy and tasty Hawaiian treats. That's because the export potential of Hawaiian produce was limited by strict quarantine restrictions and phytosanitary measures to ensure that agricultural pests such as fruit flies didn't invade the mainland. These export restrictions have cost Hawaiian growers around $300 million per year in lost sales.

Research by entomologist Peter Follett and food technologist Marisa Wall has changed all of that. The scientists, who work at the Pacific Basin Agricultural Research Center in Hilo, Hawaii, are the first to apply generic irradiation protocols to control a wide variety of quarantine insect pests found on fresh commodities.

Based partly on the scientists' extensive research, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) in 2006 published a landmark rule accepting the generic doses for treatment of Hawaiian produce. "APHIS had the courage to take the step of turning our research into regulations. Without their hard work, growers and consumers wouldn't be able to benefit from this research," says Follett.

No Pests on These Products

In 2000, the first commercial irradiation facility dedicated to treating fresh produce for export was built by Hawaii Pride LLC. Initially, the facility was unable to process large amounts of product because each type of fruit or vegetable required a different protocol for treatment.

"Quarantine or phytosanitary treatments such as heat, cold, irradiation, and fumigation are used to disinfest commodities like fruits and vegetables of insect pests before they are exported to areas where the pests aren't found," explains Follett. "Typically, entomologists have to develop

Technician Steve Brown (left) and ARS entomologist Peter Follett prepare fruit fly-infested papaya samples for x-ray irradiation treatment at Hawaii Pride in Keaau, Hawaii.

MARISA WALL (D2097-1)

Hawaiian Fruit

A technology transfer success story

treatments for one pest and commodity at a time, which can take years of research."

Seeing that Hawaii's small farmers were extremely interested in using phytosanitary irradiation as an alternative to the costly methyl bromide treatment for exports, Follett and Wall began promoting a "generic protocol" that could control a broad variety of pests on a wide range of commodities with one treatment. The scientists worked closely with Hawaii Pride, APHIS, and local growers and exporters to conduct research on using the generic treatments to control key quarantine pests.

The researchers used the Hawaii Pride facility and its new, $6 million state-of-the-art electron-beam x-ray irradiator—the only one of its kind—to test radiation limits on a variety of fruits and vegetables. "X-ray radiation penetrates the produce easily, so treatment time is short, and the required dose can be applied without changing the fruit's or vegetable's temperature," says Follett.

Follett conceived, designed, and executed extensive irradiation experiments to determine the levels needed to control quarantine insects. He found that a generic dose of 150 Grays (Gy) of radiation is suitable for controlling the three species of tephritid fruit flies found in Hawaii, which contributed to APHIS approval of this dose for all tephritid fruit flies. He also demonstrated that a generic dose of 400 Gy is broadly effective against many other pests of fruits and vegetables. This is the most widely used generic treatment today.

But just because a generic dose is available doesn't mean growers will use it. They want to ensure that their product will still be at its best when it reaches the mainland. That's where Wall comes in. She's responsible for examining product quality after exposure to radiation.

"Irradiation adds another step to the postharvest process, which puts added stress on the commodity," says Wall. "To establish maximum dose levels, we conducted tests for composition, quality, and visual damage to see exactly how much radiation the product can tolerate. We also replicated shipping and storage conditions to assess whether the consumer would receive a high-quality product."

SUZANNE SANXTER (D2094-1)

Above: Whole dragon fruit, *Hylocereus* sp., a delicious tropical fruit gaining popularity in the continental United States.
Below: Slices of fresh dragon fruit, revealing its edible flesh.

SUZANNE SANXTER (D2094-2)

MARISA WALL (D2102-1)

Biological science technician Sandra Silva analyzes peel color of irradiated dragon fruit as part of the quality analysis of irradiated tropical crops.

Wall concluded that most commodities can tolerate irradiation at levels that control pests. But she cautions that not all commodities behave the same when exposed to radiation. "We found that different varieties of a fruit or vegetable react differently to the same radiation doses. Maturity, time of harvest, and several other factors can also affect product quality."

Variations aside, Follett and Wall's research has opened up the market for Hawaiian produce. The Island State currently uses generic irradiation treatments to export 15-20 million pounds of various tropical fruits and vegetables annually.

The technology has made it easier and less costly for Hawaiian growers to share their produce with consumers on the mainland. As a result of their efforts, Follett and Wall received a 2010 Federal Laboratory Consortium Award for Excellence in Technology Transfer.

More Research Means More Produce

Hawaiian growers and exporters are not the only ones benefitting from the scientists' research. In 2009, the International Plant Protection Commission approved the generic radiation dose of 150 Gy for tephritid fruit flies, facilitating the worldwide adoption of this technology.

There are currently a handful of countries using the generic protocols on a variety of commodities. India, Thailand, Vietnam, Mexico, and Pakistan recently received APHIS approvals to export tropical fruits to the United States using generic irradiation treatments. Indonesia, the Philippines, Peru, and South Africa are awaiting their approvals.

Follett is now trying to determine whether lower doses of radiation will be effective in controlling quarantine pests. Lower doses would result in less damage to the produce, help lower the costs of treatment, and allow larger amounts of produce to be processed.

Wall is currently studying how mixtures of different fruits packed in the same box are affected during the postharvest period. Follett found that the radiation doses that have been approved by APHIS to control quarantine pests on single-commodity shipments can also be used to treat shipments containing mixed fruits and vegetables. Some fruits, however, produce more ethylene gas in response to irradiation, causing other fruits to ripen more quickly. Wall is trying to determine the right mix of fruits that can be packed together so that one day we may be able to enjoy a lovely collection of tropical fruit directly from Hawaii.—By **Stephanie Yao,** ARS.

This research supports the USDA priority of ensuring food safety and is part of Crop Protection and Quarantine, an ARS national program (#304) described at www.nps.ars.usda.gov.

Peter Follett and Marisa Wall are in the USDA-ARS Tropical Crop and Commodity Protection Research Unit, Pacific Basin Agricultural Research Center, 64 Nowelo St., Hilo, HI 96720; (808) 959-4303 [Follett], (808) 959-4343 [Wall], peter.follett@ars.usda.gov, marisa.wall@ars.usda.gov. *

The technology has made it easier and less costly for Hawaiian growers to share their produce with mainland consumers.

Tangerine Tomatoes Top Reds in Preliminary Lycopene Study

Tangerine tomatoes, named for their attractive orange color, are plump, juicy, and slightly sweeter than everyday red tomatoes. Sold seasonally at some farmers' markets and specialty grocers, these are heirloom fruits, the kind that your grandparents or great-grandparents may have planted in their garden.

Besides their appealing color and pleasing flavor, there's another reason to give these vintage tomatoes a try. A 1-month study led by Agricultural Research Service chemist Betty J. Burri and former ARS biologist Betty K. Ishida, both based in California, has provided new evidence to suggest that, ounce for ounce, tangerine tomatoes might be better sources of lycopene—a powerful antioxidant—than are familiar red tomatoes.

The difference lies in the forms of lycopene that the two tomato types provide. The *trans*-lycopene form makes up most of the lycopene in common red tomatoes. In contrast, most of the lycopene in tangerine tomatoes is *tetra-cis*-lycopene.

The California investigation and one conducted by scientists in Ohio suggest that the tangerine tomato's *tetra-cis*-lycopene is more efficiently absorbed by our bodies than is the *trans*-lycopene of red tomatoes.

For the California study, 21 healthy men and women volunteers were asked not to eat any fresh tomatoes, tomato products, or other foods rich in lycopene (watermelon or pink grapefruit, for example) other than that provided by the researchers. That instruction went into effect at the start of a 1-week "washout" period and stayed in effect throughout the rest of the study period.

In the week after the washout, volunteers ate their usual breakfast, dinner, and snacks (minus lycopene-rich foods), but came to the ARS Western Human Nutrition Research Center in Davis, where Burri is based, to have a special lunch. This meal consisted of kidney bean chili made with either red or tangerine tomato sauce. The chili, about a 2-cup serving, was accompanied by French bread, butter, and a salad of leafy greens with dressing.

Volunteers followed that regimen with another week-long "no lycopene" washout stint before switching over to a final 1-week phase featuring lunches of whichever type of chili—red or tangerine—they had not already eaten earlier in the study.

Blood was analyzed weekly for lycopene levels with a standard laboratory instrument known as a "high-performance liquid chromatograph." The analyses indicated that lycopene levels increased relative to those measured just before each 1-week chili regimen began. Total lycopene levels increased more after the tangerine tomato treatment than after the red tomato treatment.

The team also assessed oxidative damage. Lycopene and other antioxidants can, as the term implies, protect cells and "good fats"—essential fatty acids—against oxidation. Using a procedure known as a "TBARS assay," the scientists determined that oxidative damage decreased with both treatments. But decreases were greater after the tangerine-tomato regimen.

Burri and Ishida, along with former ARS visiting scientist Jung S. Seo and others, published their findings in a 2009 issue of the *International Journal of Food Sciences and Nutrition*.—By **Marcia Wood,** ARS.

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

To reach the scientists named in this story, contact Marcia Wood, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1662, marcia.wood@ars.usda.gov. *

BETTY BURRI (D2061-1)

Tangerine tomatoes might be a better source of lycopene than traditional red tomatoes.

"Fire Gel" Protects Beneficial Nematodes From Sun

PEGGY GREB (D2080-1)

Peaches grown at the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory.

The *Steinernema carpocapsae* nematode is a little worm that can protect peach and other stone fruit trees by attacking devastating borer pests. Some nematodes are pests, but these are beneficial because they can act as biological controls of the borers and other insect pests.

Trouble is, this nematode is sensitive to the sun's harmful ultraviolet rays and heat, both of which can cause desiccation—the state of extreme dryness. In time this can cause death, so the nematodes could benefit from some sort of protection when exposed to these elements.

Agricultural Research Service scientists in Byron, Georgia, are trying a novel approach to help the tiny worms. They're testing the same type of "fire gel" that has been used to help prevent the spread of fire to residential and commercial structures to see whether the gel, after it is sprayed onto fruit trees, can help nematodes avoid desiccation.

The gel creates a barrier between the fire and the structure it's protecting, preventing the spread of fire. This barrier property could also serve as a moisture "blanket" for nematodes, allowing them to attack pests above ground without being harmed by the sun.

There are two species of borers that attack peaches—lesser peachtree borers, which attack the aboveground portions of the peach tree, and peachtree borers (also known as greater peachtree borers), which attack the roots of the tree. In laboratory settings, *S. carpocapsae* nematodes proved effective in killing both borer species.

The nematodes are efficient at controlling the underground-dwelling peachtree borer but lose their effectiveness above ground. That's because the nematodes' chances of survival are far greater below ground—where the soil's moisture helps them stave off drying—than above ground, where they're exposed to sun and heat.

According to entomologist David Shapiro-Ilan, with ARS's Southeastern Fruit and Tree Nut Research Laboratory in Byron, "If fire gels can protect a house, they may be able to protect nematodes for a few days so that they can kill the lesser peachtree borer."

And he's shown that the gel does just that. Shapiro-Ilan, along with fellow Byron entomologist Ted Cottrell, tested different formulations aimed at protecting the nematodes during aboveground application, including the fire gel.

After 2 years of testing, a nontoxic, environmentally friendly brand of fire gel (Barricade) was the most effective treatment. The best part was that the gel-nematode combination left only 30 percent of the lesser peachtree borers alive in 2008 (from 100 percent initial survival), and none survived in 2009.

The scientists believe the sprayable gel could be used to protect other beneficial

PEGGY GREB (D2077-1)

Entomologist David Shapiro-Ilan (left) sprays a gel formulation onto a peach tree limb while technician Wanda Evans prepares the nematode application. The gel is being used to protect beneficial nematodes from damage due to extreme drying and UV radiation. With the protective formulation, the nematodes go to work killing harmful insect pests, such as the lesser peachtree borer.

The scientific team plans to test the fire gel on grower orchards. Horton, who also serves as an extension specialist, will be instrumental in finding these grower cooperators. Horton is developing an instructional video offering farmers tips on how best to apply the gel. Mizell will conduct field trials in Quincy, Florida, to determine the best time of year to apply the gel and to see whether Shapiro-Ilan's technology is applicable in that region.

Shapiro-Ilan is also working with ARS collaborators Bob Behle and Chris Dunlap in Peoria, Illinois, as well as Lerry Lacey in Wapato, Washington. Behle, an entomologist, and Dunlap, a chemist, specialize in formulation of microbial agents and have provided Shapiro-Ilan with some of the ingredients needed for his field trials.

Lacey, an entomologist, has developed a foam formulation that consists of wood

Fire-gel sprayed onto peach tree limbs.

PEGGY GREB (D2078-2)

species besides *S. carpocapsae.* The gel might be used in combination with other beneficial nematodes to control a wide range of pests in trees or other crops above ground.

Shapiro-Ilan and Cottrell received funding from a U.S. Department of Agriculture Pest Management Alternatives Program and collaborated with entomologists Dan Horton at the University of Georgia and Russ Mizell at the University of Florida.

fiber, wood flour, and starch. This formulation forms a protective crust, whereas the gel is sticky.

Shapiro-Ilan has tested the two formulations—gel and foam—and found that the gel worked best for borers in the southeast, possibly due to the hot, dry climate. Lacey found that the foam worked better in the wet, cool northwest, protecting nematodes that attack the codling moth, a destructive pest of apples and pears. Shapiro-Ilan and Lacey will continue to test the formulations under a variety of conditions.

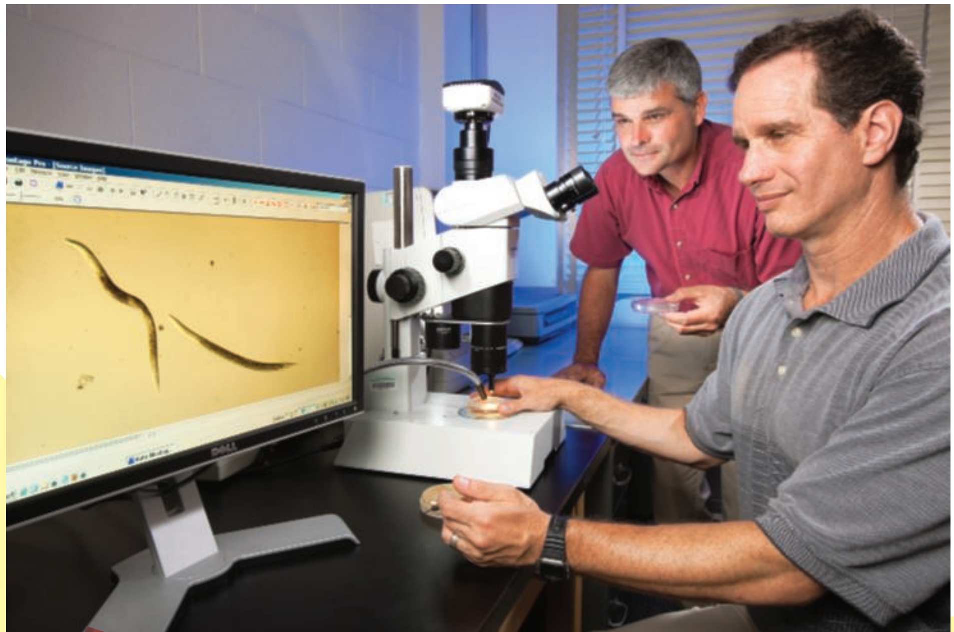
The scientific team is researching how to further optimize application rates and timing and to perform large farm-scale tests using air-blast sprayers to apply the fire gel. The scientists will also test air handgun sprayers, which efficiently disperse the fire gel in a uniform spray pattern. Additional laboratory tests are being conducted in search of superior nematode strains.

"We're going to test how much and how often we'd like to disperse the fire gel through these means," said Shapiro-Ilan, who plans to work with small and organic growers first and continue with large-scale growers in the next few years. "We'd like to make this process as efficient and economical as possible so we can get the most bang for our buck. Growers are savvy enough that if something makes economic sense, they're going to do it."—By **Alfredo Flores,** formerly with ARS.

This research is part of Crop Protection and Quarantine, an ARS national program (#304) described at www.nps.ars.usda.gov.

David I. Shapiro-Ilan and Ted Cottrell are at the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory, 21 Dunbar Road, Byron, GA 31008; (478) 956-6444 [Shapiro-Ilan], (478) 956-6448 [Cottrell], david.shapiro@ars.usda.gov, ted.cottrell@ars.usda.gov. *

PEGGY GREB (D2082-1)



Entomologists Ted Cottrell (above left) and David Shapiro-Ilan observe beneficial nematodes *(Steinernema carpocapsae)* that are used to control the lesser peachtree borer. Shapiro-Ilan and Cottrell developed a sprayable gel as a novel method for protecting the nematodes from desiccation (extreme dryness) and UV radiation.

PEGGY GREB (D2081-1)

PEGGY GREB (D2079-1)

Inset: A lesser peachtree borer larva *(Synanthedon pictipes)* emerging from a wound it made in a peach tree.

Right: A wound in a peach limb made by lesser peachtree borer *(Synanthedon pictipes)*.

Examining Climate Change Effects on Wheat

THOMAS CLARKE (D2083-1)

Aerial view of Hot Serial Cereal experiment shows the effects of turning up the heat on wheat. The three lightly shaded strips of wheat in the center were planted in September 2008 and were each divided into three plots: a heated plot with a heating apparatus (shown as a white panel), and reference and control plots where no heat was applied. Wheat in the heated plots, shown as circular patches near each heater, has already been harvested because it grew faster and matured earlier than controls. The dark-green plots on the sides were planted at other times in 2008 and 2009.

Increasing temperatures can drastically reduce crop yields, make irrigation a necessity, and increase the threat of drought. So for wheat growers in the southwestern United States and elsewhere, climate change is a major concern. Agricultural Research Service researchers at the U.S. Arid-Land Agricultural Research Center in Maricopa, Arizona, have been helping growers prepare for the changing times by turning up the heat in experimental wheat fields to levels anticipated by 2050.

"No one knows exactly how changing conditions will affect yields in the decades ahead, and we're trying to give growers an idea about what they might expect, and how they can address warming issues and minimize losses," says Bruce Kimball, a retired ARS soil scientist who was the project leader.

In Arizona, wheat is normally planted in midwinter. It is harvested in late May and irrigated throughout its growing season. Temperatures can range from below freezing in winter to above 100˚F in May.

Kimball, ARS plant physiologists Gerard Wall and Jeffrey White, and agronomist Michael Ottman of the University of Arizona planted wheat every 6 weeks in separate plots between March of 2007 and May of 2009. They applied heat to 6 of the 15 plantings, warming the crops that were planted in March, September, and December. They measured canopy conditions to make sure temperatures in the heated plots rose by 2.7˚F in the daytime and by 5˚F to 6˚F at night. They call the effort the "Hot Serial Cereal" project because they grew wheat, a cereal crop, in a series of plantings and heated the plants as they grew.

To warm the plots, the researchers used six 1,000-watt infrared heaters suspended above the plants in a hexagonal pattern, forming a temperature free-air controlled enhancement (T-FACE) apparatus. Developed by Kimball, T-FACE enables scientists to raise the temperature of experimental crops in open fields. The technology is also being used by ARS researchers on grazinglands in Wyoming and soybean fields in Illinois and by more than a dozen other research groups around the world.

The researchers measured growth, yield, and several other soil and plant physiological variables. As expected, the heaters accelerated growth, increased soil temperatures, reduced soil moisture, induced mild water stress on the crops, and had a nominal effect on photosynthesis. But effects on yields depended on when the wheat was planted. When heat was applied to wheat planted normally, in midwinter, its growth cycle was ahead by a week. There were no major differences in yield. Adding heat to wheat planted in March reduced yields by half. Most surprising, rather than reducing yields, adding heat to wheat planted in September protected the plants from damaging frosts between Christmas and New Year's both years. Heated plots showed only moderate yield loss, whereas the wheat in the unheated control plots yielded nothing.

The results may provide guidance for adjusting planting schedules as the climate warms. The researchers are developing computer models that could be applied to any region, making the results useful for adapting planting schedules to changing climates worldwide.

This research supports the USDA priority of responding to climate change.—By **Dennis O'Brien,** ARS.

This research is part of Global Change, an ARS national program (#204) described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Dennis O'Brien, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1624, dennis.obrien@ars.usda.gov. ✻

Studying Streambanks Reveals Their Weaknesses and Strengths

When some experts study bank failures, they aren't scrutinizing the books of badly run financial institutions. Instead, they're occasionally wading through Mississippi's sediment-laden waterways to develop dynamic models of erosion processes and streambank collapse.

"The problem is that the primary source of sediment in many Mississippi streams and rivers is from streambank failure, not from field runoff," says Agricultural Research Service hydrologist Glenn Wilson, who works at the ARS Watershed Physical Processes Research Unit in Oxford, Mississippi. "Up to 80 to 90 percent of sediment in these streams can be due to bank collapse."

The sedimentation of streams, rivers, and other waterways is a global concern, and the U.S. Environmental Protection Agency lists sediment as the most common pollutant of U.S. rivers, streams, lakes, and reservoirs. Trapped sediment can reduce the useful lifespan of dams and reservoirs, exacerbate flooding, harm aquatic plants and animals, and transport other pollutants downstream. So over the years, billions of dollars have been spent on streambank protection and restoration efforts to stem erosion and reduce sedimentation loads.

Even though the sediment in streams and rivers is often attributed to erosion and runoff from farm fields, Wilson turned his investigations to the contributions of streambank erosion. He teamed up with Oklahoma State University scientist Garey Fox to study how seepage—the lateral movement of water through the ground—could prompt conditions that led to bank failure.

GLENN WILSON (D2063-1)

An example of seepage erosion from a section of Goodwin Creek in Mississippi.

Wading Through the Data

The researchers started their project with a field survey of streambanks that were severely undercut and prone to collapse. "This type of undercutting has historically been attributed to streamflow," Wilson says. "Others have noted that during high-flow events, the increased speed and volume of the streamflow cuts into the bank and weakens it. Then when the water level drops, the bank fails."

But Wilson and Fox found examples of undercut bank failures that had occurred in low-flow streams. When they took a closer look at these banks, they saw evidence that seepage out of streambanks was eroding out layers of soil. The eroded soil layers washed down the face of the streambank and into the stream itself, adding to the sediment load in the stream and leaving the bank weakened and vulnerable to collapse due to having undercuts from the washed-out layers.

"When we were first looking at this, bank stability models didn't account for subsurface flow—just for surface water flow," Wilson explains. "So our existing streambank models were actually missing key mechanisms in bank failure."

The scientists gathered enough field data on seepage erosion processes to develop lab models and refine their understanding of how seepage could exacerbate eventual streambank failure. In the lab, they could control bank depth and seepage flow rates—and they could safely observe the sometimes-sudden collapse of a massive wall of dirt.

GLENN WILSON (D2062-1)

ARS hydrologist Glenn Wilson (left), graduate student Raja Periketi (center), and Oklahoma State University scientist Garey Fox use a simulated streambank to conduct laboratory experiments of seepage erosion on streambank failure. Periketi is measuring the lateral extent of a mass failure caused by seepage erosion.

"Streambanks can be 10 to 20 feet high, and the subsurface seeps can form at any depth," Wilson says. "We couldn't measure peak seepage rates in the field under all the conditions we'd like because it was just too dangerous—the banks collapse during storms, and sometimes they're deep enough to bury you."

Wilson and Fox confirmed for the first time that a stable streambank can quickly become unstable when seepage erosion is added to the mix of factors that promote bank failure. The probability of failure reached 100 percent when the degree of undercutting reached about 30 to 50 millimeters (1 to 2 inches) into the bank face. The researchers concluded that streambank failure may stem as much—or more—from the effect of seepage erosion undercutting the streambanks as from the added weight of the waterlogged soil as seepage increases.

Wilson included their calculations into the Bank Stability and Toe Erosion Model, a program developed at the ARS National Sedimentation Laboratory that calculates the likelihood of streambank failure for new or existing banks and simulates the efficacy of different approaches for protecting the streambank from erosion. "Our big payoff for this research has been recognizing and understanding the seepage erosion process and how it contributes to bank failure," Wilson says. "Looking back, I'd say the biggest surprise from this work is that the role of seepage had been overlooked for so long."

Putting Green Stuff in the Bank

Down the hall, ARS geologist Natasha Bankhead has also been studying streambanks, but she's focusing on how removing mature plants can weaken the structures—and how adding young riparian plants can support them. "Plant roots reinforce the soil in the same way that rebar can be used to reinforce concrete," Bankhead says.

Plants vary in their effectiveness as streambank sentinels. Grasses have thin, dense roots that form an underground net and can protect the soil on shallow banks from eroding. Taller banks need more substantial reinforcement, but trees don't always fit the bill.

"Trees don't have much of an impact on bank stability until they're around 7 to 10 years old," Bankhead says.

As part of her research, Bankhead is testing the tensile strength of roots—the force required to pull a root to the point where it breaks—of different tree species. Her studies indicate that in the southeastern United States, willows and other primary succession trees growing along streambanks have lower tensile strength levels. Trees that are part of the later successional stages, like sycamores, river birches, oaks, and cottonwoods, have higher tensile strengths. But the root structures don't just provide physical support.

"In the summer, trees remove a huge amount of moisture from soil through evapotranspiration," Bankhead explains. "And bank stability increases as soil moisture decreases, so in the summer, the effect from evapotranspiration actually provides more structural support to the streambanks than the roots do."

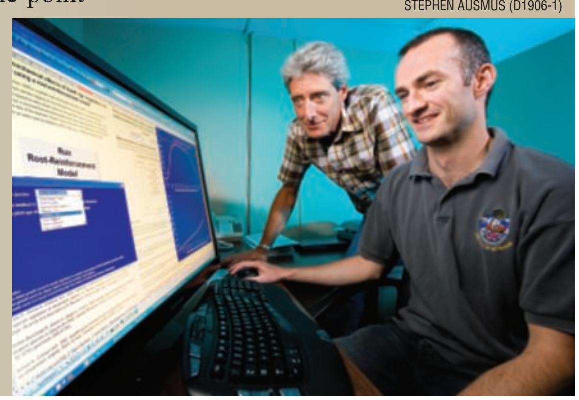
Bankhead has used her findings to develop a program called "RIPROOT," which models the effects of riparian vegetation on streambank stability. She is collaborating with other researchers to test it in watersheds across the country.

"We've made a lot of advances in understanding these processes and incorporating them into mechanistic, process-based models," Wilson says. "But we need to continue collaborations with soil scientists, geotechnical engineers, hydraulic engineers, and hydrologists to fully understand and integrate subsurface-flow and soil-erosion processes."—By **Ann Perry,** ARS.

This research is part of Water Availability and Watershed Management, an ARS national program (#211) described at www.nps.ars.usda.gov.

Glenn V. Wilson and Natasha L. Bankhead are in the USDA-ARS Watershed Physical Processes Research Unit, 598 McElroy Dr., Oxford, MS 38655; (662) 232-2927 [Wilson], (662) 281-5712 [Bankhead], glenn.wilson@ars.usda.gov, natasha.bankhead@ars.usda.gov. *

STEPHEN AUSMUS (D1906-1)



ARS geologist Andrew Simon (left) and University of Tennessee-Knoxville scientist Robert Thomas use the RIPROOT model, a component of the Bank Stability and Toe Erosion Model, to estimate the effects of riparian vegetation on streambank stability.

PEGGY GREB (D2095-1)

Agro/Environmental Data at Your Fingertips

Research leader Laj Ahuja (left) and collaborator Jack Carlson check the ease of entering farm operation information on a smart phone instead of a tablet computer.

A farmer and a conservationist examine a gully in a field and wonder how it formed, how much erosion it causes, and what they can do to repair it. The conservationist picks up a mobile phone for answers. The phone's GPS (Global Positioning System) locates the gully's coordinates and connects to a computer model service that calculates soil erosion under various agricultural management practices. The answers return quickly, borrowing the power of a large, remote, Internet-based data center.

That scenario will be real in the not too distant future, since the framework for making the science available, the Object Modeling System (OMS), is operational and available worldwide to anyone at oms.javaforge.com, and work has begun to design applications that connect to the model services.

"OMS is a computer framework to easily create and update problem- or region-specific compatible models, using science modules chosen from a library. It provides a uniform system of evaluation and delivery of models to users," says Laj Ahuja, research leader at the Agricultural Systems Research Unit in Fort Collins, Colorado. OMS was created by ARS in partnership with the USDA Natural Resources Conservation Service (NRCS), Colorado State University (CSU), U.S. Geological Survey, and other collaborators.

The current primary ARS application of OMS is to deliver science model services to NRCS in support of its Conservation Delivery Streamlining Initiative, thus improving technical assistance to farmers and ranchers.

Olaf David, OMS architect and computer scientist with CSU at Fort Collins, explains that OMS will house many agro-environmental modules and models. He says modelers from around the world can collaboratively develop and contribute to models in OMS. "Modelers from Europe are already doing that," David says. "Although ARS and other organizations developed the framework, it is also part of the global modeling community."

ARS and CSU modelers are using OMS to support USDA programs. "The Precipitation and Runoff Modeling System has been incorporated into the NRCS water supply forecasting this year, and the new AgES-W conservation assessment model is undergoing validation," says Frank Geter, team leader with the NRCS Information Technology Center at Fort Collins.

Says Jack Carlson, retired NRCS chief information officer and project collaborator, "Software that accesses science models in OMS will help conservationists devote more of their time to their primary mission, providing science-based conservation planning and technical assistance to farmers."

"Every workday, conservationists service more than 5,000 conservation plans. In the past, running models has been a laborious process. OMS has been designed to improve efficiency by 80 to 90 percent," Carlson says.

Just as millions of people do daily with online maps, field conservationists will zoom to their area of interest on their smart phones or wireless laptops. Data embedded in resource maps for the area will be relayed to OMS-hosted model services to compute answers leading to recommendations for the resource problems the farmer has identified.

"Computer models, managed in frameworks like OMS, coupled with field experiments and wireless delivery devices are the next frontier for agricultural research and technology transfer," says Ahuja. "These frameworks harness the growing power of computer technology, enabling it to reach its full potential."—By **Don Comis,** ARS.

This research is part of Water Availability and Watershed Management (#211), an ARS national program described at www.nps.ars.usda.gov.

To reach scientists mentioned in this story, contact Don Comis, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1625, donald.comis@ars.usda.gov. *

The Agricultural Research Service has about 100 labs all over the country.

Locations Featured in This Magazine Issue

Corvallis, Oregon
3 research units ■ 152 employees

Yakima Agricultural Research Laboratory, Wapato, Washington
1 research unit ■ 56 employees

The Vegetable and Forage Crop Research Unit, Prosser, Washington
1 research unit ■ 34 employees

Davis, California
5 research units ■ 111 employees

U.S. Pacific Basin Agricultural Research Center, Hilo, Hawaii
2 research units ■ 69 employees

U.S. Arid-Land Agricultural Research Center, Maricopa, Arizona
3 research units ■ 88 employees

Fort Collins, Colorado
5 research units ■ 143 employees

National Center for Agricultural Utilization Research, Peoria, Illinois
7 research units ■ 226 employees

Oxford, Mississippi
3 research units ■ 102 employees

Henry A. Wallace Beltsville Agricultural Research Center, Beltsville, Maryland
30 research units ■ 953 employees

J. Phil Campbell Sr., Natural Resource Conservation Center, Watkinsville, Georgia
1 research unit ■ 25 employees

Southeastern Fruit and Tree Nut Research Laboratory, Byron, Georgia
1 research unit ■ 48 employees

U.S. Department of Agriculture
Agricultural Research Magazine
5601 Sunnyside Ave.
Beltsville, MD 20705-5130

Official Business

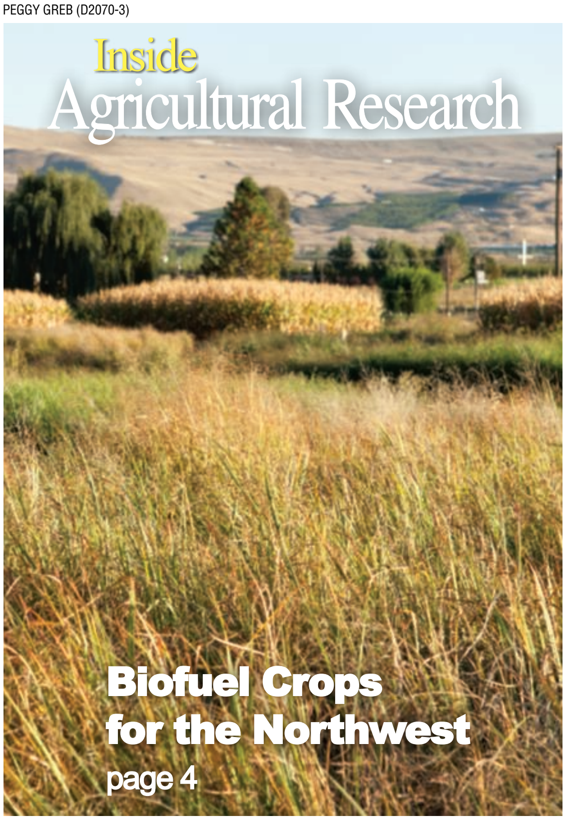
PRST STD
Postage and Fees Paid
U.S. Department of Agriculture
Permit No. G-95

Please return the mailing label from this magazine.

To stop mailing ☐

To change your address ☐

PEGGY GREB (D2070-3)

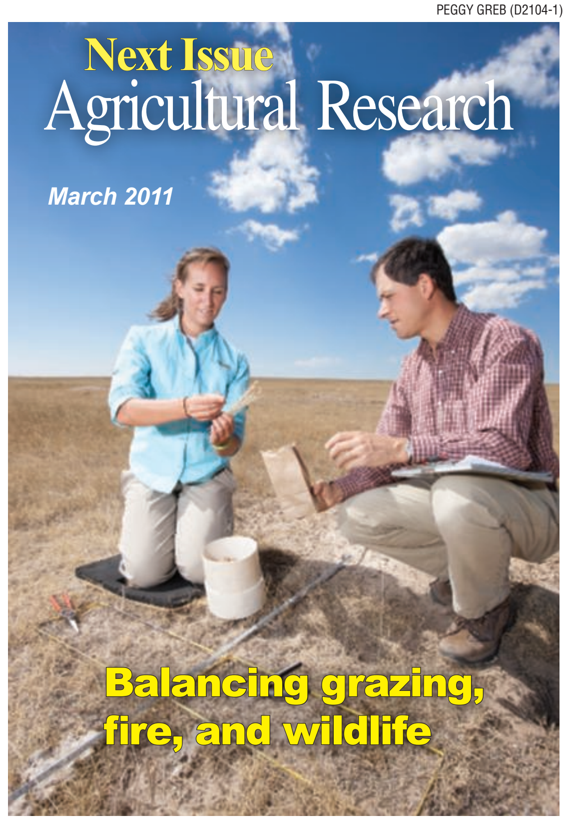


Subscribe

for $60.00 per year
($84.00 foreign addresses)
Visa and Mastercard accepted.
Prices subject to change.
Order By:
Fax: (202) 512-2104
Phone: (202) 512-1800
Mail:
New Orders
Superintendent of Documents
P.O. Box 371954
Pittsburgh,
PA 15250-7954

bookstore.gpo.gov.

PEGGY GREB (D2104-1)



Visit us on the Web at ars.usda.gov/ar