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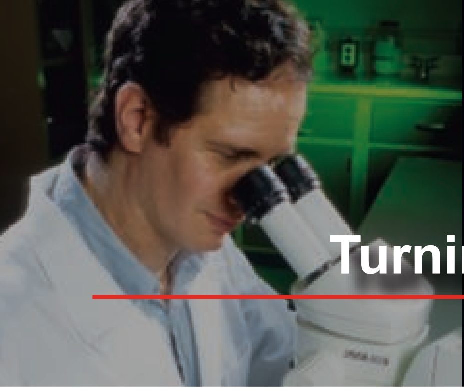
Agricultural Research

Whole-Grain Flour Power

page 18

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



FORUM

Turning to Nature To Address Some of Our Most Vexing Problems

PEGGY GREB (K9858-1)

JACK DYKINGA (K7549-7)

The problems facing agriculture today are numerous and daunting. How do we maintain the quality of our soils? How do we provide a sufficient supply of food and fiber as the climate changes, water becomes more precious, and seasons and growing patterns are inevitably altered?

As a scientific research agency, how should the Agricultural Research Service address such complicated issues? Our scientists are meeting that challenge by looking to nature for solutions. A number of ARS efforts that focus on natural approaches to the challenges we face in agriculture today are described in this issue.

Depleted soils are a major challenge in many areas. At least part of the solution may be found by looking at North America's ecological history. Brush fires once burned freely over the prairies. Those prairie fires, damaging as they were, were part of the land's natural life cycle.

We now know that the charred remains of those grasses enriched the soil and made it fertile. ARS scientists are examining how the type of residue, or "biochar," produced by those fires can be exploited as a natural resource. The research, at ARS sites across the United States, is showing how biochar can be used not only to enrich soils, but also to reduce greenhouse gas emissions from soil.

ARS scientists in Florence, South Carolina, and Kimberly, Idaho, have examined how different biochars affect the water-holding capacity of soils in those regions. The research has uncovered evidence that biochar made from switchgrass can enhance soil moisture in both soil types, and the benefit is twofold: more productive soil and more carbon stored underground instead of being released into the atmosphere.

ARS scientists in Ames, Iowa, have found that adding biochar to the soil has similar benefits—sequestering more carbon in the soil and reducing nitrous oxide emissions. Their colleagues in Prosser, Washington, are working on a technology that uses biochar to remove nitrogen and phosphorus from dairy manure and produces pellets that may be a suitable fertilizer. See the story on page 4 for details on ARS's biochar studies.

In efforts to promote adequate food and fiber production, ARS scientists in Byron, Georgia, and Stoneville, Mississippi, have developed a unique way of applying biological control nematodes to soil for control of larval stages of some crop pests. Some species of nematodes are well suited for biocontrol because of their entomopathogenic (insect-killing) capability and host specificity, meaning they attack only certain insects. Once inside the host insect, these nematodes feed and mass produce, and in a week or two, a new generation of nematodes emerges to continue the cycle.

The beneficial nematodes, naturally contained inside the cadaver of the host, can be applied to the soil by simply applying the cadavers to the soil, but the process is not without its problems. The cadavers sometimes stick together or fall apart. Sandwiching the cadavers between masking tape solves the problem, however, and makes for an easy way to protect, transport, and apply the cadavers to the soil. See story on page 12.

Peach growers in the Southeast would like a preplant cover crop to reduce their need to fumigate to control root-knot nematodes and ring nematodes. ARS researchers in Beltsville, Maryland, and Byron, Georgia, tested four tall fescue varieties for their ability to combat the soil pests. They found one that makes it impossible for some nematodes to reproduce. The results so far are limited to greenhouse studies, and field trials are ongoing. See story on page 14.

The safety of our food is another concern. Foodborne pathogens are found naturally in the digestive tracts of farm animals, and reducing the number of those pathogens without antibiotics would be a critical step in improving food safety. ARS researchers at College Station, Texas, have found that orange peels fed to cows can help. The peels contain compounds that, in the cow's intestinal tract, reduce populations of potentially harmful *E. coli* and *Salmonella*. See story on page 10.

These efforts address issues that should be a concern not just to growers and those who care about the environment, but to anyone who shares in the fruits of our agricultural bounty. Together we can meet these challenges by producing the agricultural commodities we need in ways that allow us to be stewards of the land.

Judith B. St. John
ARS Associate Administrator
Beltsville, Maryland

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Solving Problems for the Growing World

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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

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PEGGY GREB (D2336-1)

Cows seem to enjoy orange peel and pulp. But these citrus byproducts are more than just tasty and nutritious; they also have an antimicrobial effect in the cow's gut. Story begins on page 10.

Cover: Holiday cut-out cookies made with healthier whole-grain wheat flour. In the future, cookies made with whole-grain wheat flours tested by the Soft Wheat Quality Laboratory in Wooster, Ohio, could be part of your holiday festivities.

Photo by Peggy Greb. (D2342-1)

Carefully Unraveling the Intricacies of Biochar

DAVID LAIRD (D2343-1)

When fires burned freely across the North American prairies, they left behind charred material that helped form the region's dark, fertile soils. In South America, pre-Columbian Indians used slash-and-char practices to clear land for farming, which incorporated large amounts of char into the highly weathered soils of the Amazon. This char became a key building block in the development of the rich "terra preta"—or black earth—that sustained agriculture in the Amazon for more than 1,000 years.

Today, Agricultural Research Service scientists are learning more about "biochar," the name for the charred biomass created from wood, plant material, and manure that has been used to improve soil fertility and remediate environmental contaminants. The multi-location effort is still under way, but preliminary results suggest that adding

REBECCA COCHRAN (D2344-1)

Bulk hardwood biochar prior to application on plots near Ames, Iowa.

biochar to agricultural soils could rebuild soil fertility levels and improve nutrient and water retention. Biochar can even "sequester" carbon from plant materials by storing it underground, where it slowly decomposes and makes only a minimal contribution to the emission of the greenhouse gas carbon dioxide. So ARS scientists are working diligently—and carefully—to understand how biochar interacts with soil and crops so that the potential benefits observed in the laboratory can become economically viable realities in the field.

First Steps

Much of the ARS field work on biochar started at the National Laboratory for Agriculture and the Environment (NLAE) in Ames, Iowa. During November 2007, NLAE scientists began the first of six multi-year field studies at ARS locations around the country to assess how biochar affects crop productivity and soil quality. NLAE scientists amended 24 plots (almost 8 acres) of corn with biochar made from hardwood biomass. Twelve plots had almost 8,800 pounds of biochar per acre, and 12 had almost 16,000 pounds per acre. But no significant difference was observed in the 3-year average grain yield from either treatment.

Other small-scale ARS field and laboratory studies in Idaho, Kentucky, Minnesota, South Carolina, and Texas showed that hardwood biochar could improve soil structure and increase the ability of sandy soils to retain water. But soil fertility response was more variable.

These results underscore what ARS scientists already knew: Biochar characteristics vary widely, depending on the feedstock used to make it, the time spent in the pyrolyzer—a device that uses heat to break down the biomass in the absence of oxygen—the temperature used during pyrolysis, the feedstock's moisture content, and other factors. Because of structural differences, some biochars break down more quickly in soil than others. Biochars can also differ in particle size, porosity, surface area, pH, and biologically active and available compounds. So even though there's already a lot of public enthusiasm about using biochar in agricultural production, ARS scientists are much more cautious about the possibilities.

Biochar pellets in Prosser, Washington, made from dairy cow manure and used to capture phosphorus from dairy lagoons.

ARS soil scientist Doug Karlen, who is the research leader of the ARS Soil, Water, and Air Resources Research Unit at NLAE, has been involved with the biochar studies from the outset. "Now we're studying how crops respond to soils that have been amended with biochar made from corn stover," he says. "We didn't see a significant response when we amended an acre with 8 tons of biochar made from hardwood, so now we're amending fields with as much as 50 tons of corn stover biochar per acre."

Finding What Works Where

"We need to make sure that the biochar will actually improve the condition of the soil where it is being used," says soil scientist Jeff Novak, who coordinates the ARS multi-location effort to learn more about biochar dynamics under different real-world field conditions. "We want to ensure that the correct biochar is applied to the right soil so that we avoid decreasing soil quality."

Novak, who works at the ARS Coastal Plains Soil, Water, and Plant Research Center in Florence, South Carolina, is working with other scientists to manufacture "designer biochars" with properties tailored to remediate specific soil characteristics. He led a laboratory study to learn more about the characteristics of different biochars and to see which biochars could improve the sandy soils found on the Carolina coastal plain and the silt loam soils of the Pacific Northwest, which are derived from volcanic ash and windblown sediment known as "loess."

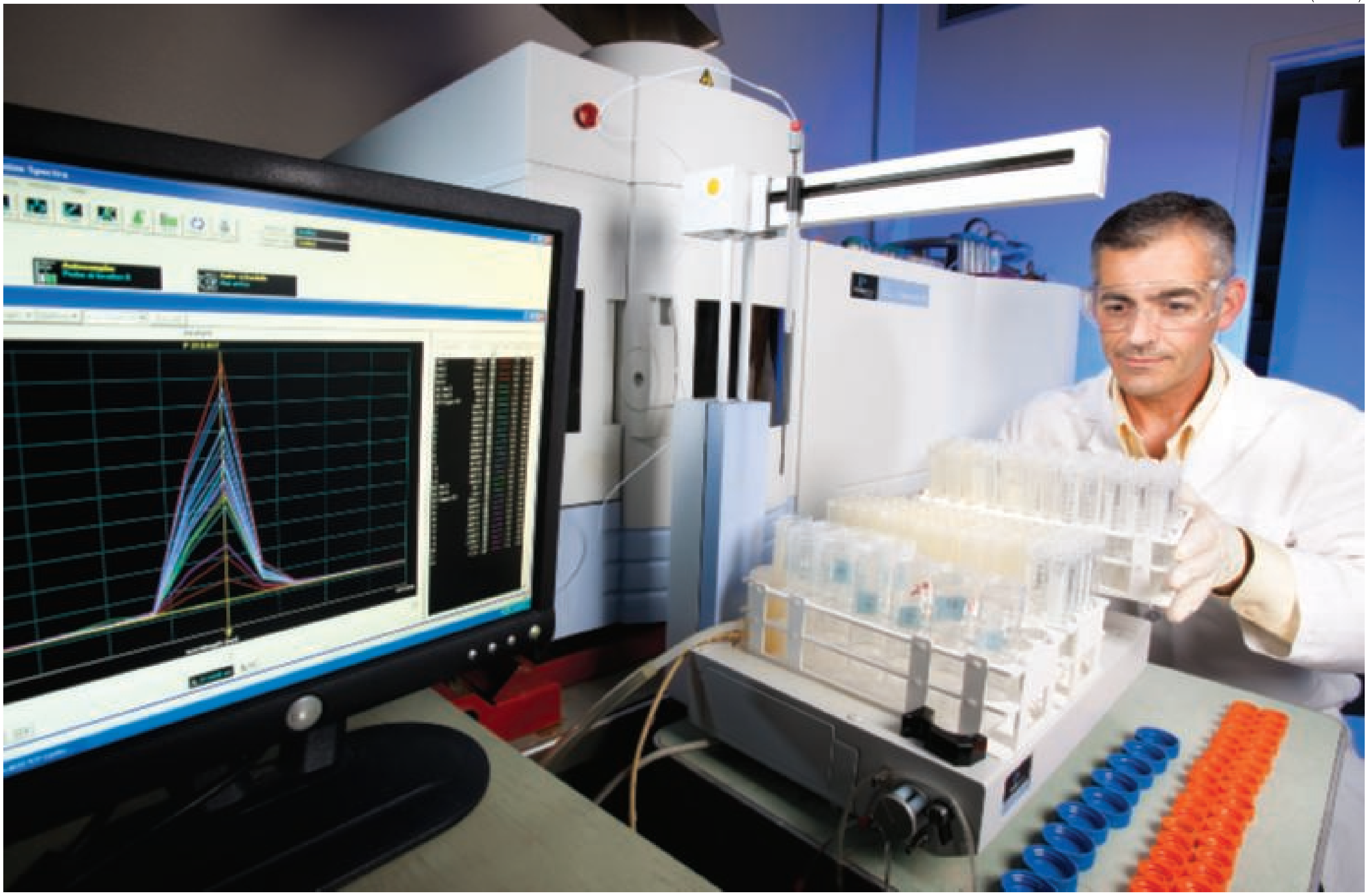
Several other Florence researchers, including soil scientist Warren Busscher, environmental engineer Kyoung Ro, agricultural engineer Keri Cantrell, and microbiologist Tom Ducey, participated in the study. Other ARS partners included chemist Isabel Lima, who works in the ARS Commodity Utilization Research Unit in New Orleans, Louisiana; soil scientist Jim Ippolito, with the Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho; and ecologist Harry Schomberg at the J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, Georgia.

The team made biochars from peanut hulls, pecan shells, poultry litter, switchgrass, and hardwood waste products. By pyrolyzing these materials at different temperatures, the researchers produced nine different types of designer biochars.

Lettuce growing in Minnesota field plots amended with 20,000 pounds of macadamia nut shell biochar per acre. The study evaluated how the biochar affects crop yield, soil fertility, and greenhouse gas production from the field.

AMANDA BIDWELL (D2345-1)

PEGGY GREB (D2326-1)



ARS soil scientist Jim Ippolito conducts analysis of essential plant elements from soils amended with biochar in Kimberly, Idaho.

Then the biochars were mixed into one type of sandy soil and two silt loam soils at the rate of about 20 tons per acre. The test soils were leached with water every month.

After 4 months, the team found that biochars produced from switchgrass and hardwoods increased soil moisture storage in all three soils, but biochar made from the other biomass sources did not. They saw the greatest moisture increase in soils amended with switchgrass biochar produced via high-temperature pyrolysis—almost 3 to 6 percent higher than a control soil sample. Biochars produced at higher temperatures also decreased soil acidity, and biochar made from poultry litter greatly increased soil levels of available phosphorus and sodium.

Results also indicated that switchgrass biochar amendments could extend the window of soil water availability by 1.0 to 3.6 days for a soybean crop in Florence and could increase soil water availability for crops grown in Pacific Northwest silt loam soils by 0.4 to 2.5 days.

These results support hopes that agricultural producers might someday select feedstocks and pyrolysis processes to make designer biochars with characteristics that target deficiencies in specific soil types.

Karamat Sistani, research leader at the Animal Waste Management Research Unit in Bowling Green, Kentucky, is part of the ARS biochar team. “In 2010 we started a field study on combining biochar with poultry manure to see how microorganisms and nutrients in the manure affect biochar efficiency in improving soil quality and corn yield,” Sistani says. “We also want to see if it has any efficacy in mitigating greenhouse gas emissions of nitrous oxide, methane, and carbon dioxide.”

The Bowling Green researchers will also be determining whether biochar amendments can help improve the nutrient-holding capacity of Kentucky limestone karst soils, which develop large cracks that allow water and fertilizers to move quickly through the subsoil. In addition, Bowling Green hydrologist Carl Bolster and research associate Sergio Abit are conducting a lab study to see whether biochar affects the movement of pathogens like *Escherichia coli* in the soil.

The Results Aren’t All In Yet

In Kimberly, Idaho, Jim Ippolito and soil scientist Rick Lentz are studying how three different soil amendments—biochar, manure, or a biochar-manure combination—affect soil quality and crop response in the region’s calcareous soils. During the first study year, biochar-amended soils showed no real improvement in nutrient levels, aside from an increase in manganese, which is an essential plant nutrient, and a slight increase in total organic carbon. Soils amended with manure also had increased levels of manganese and of other plant nutrients.

“Both manure and biochar applied alone increased soil manganese, but their combined effect was synergistic,” Lentz says. “In plots where soil was amended with a biochar-manure mix, the total increase in manganese was greater than what we would have obtained from just adding the manganese increase from biochar to the manganese increase from manure."

However, during 2010, fields amended with biochar had a 31-percent crop yield *decrease,* along with a 33-percent decrease in nitrogen uptake. Sulfur uptake in fields amended by biochar also decreased 7 percent.

"We think that the biochar is somehow inhibiting nitrogen and sulfur uptake, maybe by stabilizing the soil organic matter. This would reduce the mineralization rate of soil organic matter and decrease the availability of nitrogen and sulfur to the crop," Lentz says. "After biochar is added to soil, its chemical and physical characteristics will change with time, so its effect on soils and crops may change accordingly."

The third year of the study will help determine whether the 2010 results bear further investigation or were just a fluke. But the findings already demonstrate that biochar amendments might not always work the way farmers want them to work.

Greenhouse Gas Emissions and Ethylene

In Minnesota, ARS scientists are studying biochar activity in soils formed from glacial deposits. Soil scientists Kurt Spokas and John Baker, who both work in the ARS Soil and Water Management Research Unit in St. Paul, found that amending glacial soils with biochar made from macadamia nut shells reduced a range of greenhouse gas emissions.

The scientists conducted laboratory incubation studies by amending the glacial soils with biochar at levels from 2 to 60 percent. They found that emission levels of carbon dioxide and nitrous oxide were suppressed by all amendment levels, but the nitrous oxide suppression was notable only in soils amended with 20, 40, or 60 percent biochar. The amended soils also had lower microbial production of carbon dioxide and lower volatilization rates for the pesticides atrazine and acetochlor.

"Now we're looking at how volatile organic compounds, or VOCs, in biochar affect soil microbe activity," says Spokas. "Since biochar is a product of thermal-chemical conversion, it has the same VOCs that we find in smoke and soot, like benzene and toluene. We've already identified 200 different VOCs in some biochars, which is significant, because we want to use clean biochar for agricultural production."

Spokas and Baker also conducted the first study that documented the formation of ethylene—a key plant hormone that helps regulate growth—from biochar and soils amended with it. They found that ethylene production in biochar-amended non-sterile soil was double the level observed in biochar-amended sterile soil. This strongly suggests that soil microbes are active in this biochar-induced ethylene production and that the ethylene might be involved in plants' reaction to biochar additions, since even low ethylene concentrations produce various plant responses.

Cleaning Up With Biochar

ARS scientists have also spent years investigating the use of biochar for environmental remediation. Retired ARS chemist Wayne Marshall, who worked at the ARS Southern Regional Research Center in New Orleans, Louisiana, started pursuing this line

STEPHEN AUSMUS (D114-17)

In New Orleans, technician Renee Bigner places poultry litter pellets into a furnace to make biochar via slow pyrolysis.

of research in the 1990s. He and Lima found that charred poultry litter is especially adept at removing hard-to-capture heavy metals like copper, cadmium, and zinc from wastewater. They produced pellets, granules, and powders made from the char for use in water tanks, columns, and other filtering structures.

The New Orleans scientists also developed a method for making carbons that have increased surface area for adsorption or chemical reactions. They did this by pelletizing ground poultry litter and then heating the pellets at high temperatures via slow pyrolysis to produce steam-activated char. ARS was issued two patents on the process, which Lima says could be used to replace traditional activated carbon adsorbents in air or liquid-waste cleanup applications.

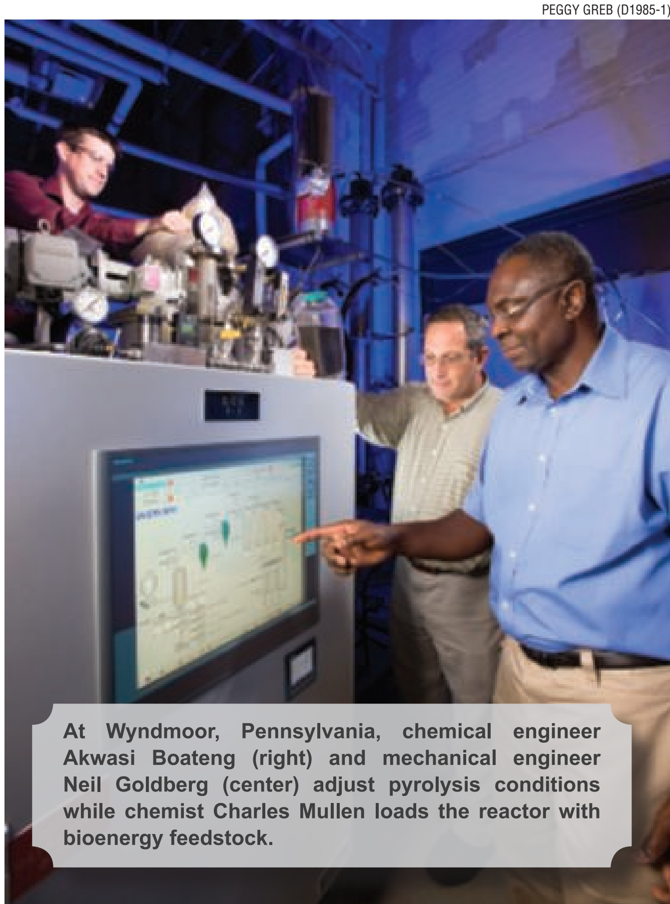
Since 2006, chemical engineer Akwasi Boateng, who works at the ARS Sustainable Biofuels and Co-Products Research Unit in Wyndmoor, Pennsylvania, has helped lead ARS studies of biochar production via fast pyrolysis. Other Wyndmoor scientists contributing to these projects include research leader Kevin Hicks, chemist Charles Mullen, and mechanical engineer Neil Goldberg.

"We use fast pyrolysis when we produce bio-oil from biofeedstock to maximize fuel production, but this process produces a biochar byproduct that has a lower surface area," says Boateng. "We'd like to improve the biofuel production process so that it also yields biochar that has a high surface area. This would make it more structurally suited to use as an activated charcoal and as a soil amendment. Identifying this kind of process could help make the biochar use in soils economical."

As part of this effort, Boateng and Lima worked with other scientists in Wyndmoor and New Orleans to see whether steam activation would increase the ability of fast-pyrolysis biochars to adsorb toxic metals. They found that biochars made from broiler litter and alfalfa stems had the highest pollutant-uptake levels.

ARS microbiologist Hal Collins, who works at the Vegetable and Forage Crop Research Unit in Prosser, Washington, is exploring similar territory by evaluating the production of bio-oil and biochar from waste materials like wheat straw, logging debris, and manure. "There are a lot of concentrated animal-production facilities in the Pacific Northwest, and there's not a lot of room available to store manure," says Collins. "Nutrient runoff from these sites can potentially pollute nearby water sources, so using the manure to produce bio-oil and biochar could be one mechanism for controlling nutrients at dairy facilities."

PEGGY GREB (D1985-1)



At Wyndmoor, Pennsylvania, chemical engineer Akwasi Boateng (right) and mechanical engineer Neil Goldberg (center) adjust pyrolysis conditions while chemist Charles Mullen loads the reactor with bioenergy feedstock.

In one test, Collins made biochar from plant fibers remaining after processing dairy manure through an anaerobic digester used to capture methane from manure. He used that biochar to adsorb phosphorus present in the digester effluent. He found that the biochar removed 32 percent of the phosphorus from the effluent, and when the biochar was used as fertilizer, 13 percent of the adsorbed phosphorus was immediately available for plant uptake.

Given these results, Collins believes that biochars could help mitigate nutrient runoff but agrees that much more work is needed on the potential benefits and drawbacks. "Using this biochar to fertilize fields is not like using phosphorus fertilizer," he says. "We can add 200 pounds of fertilizer per acre to support plant growth, but we'd need to add 2 to 3 tons of the biochar to add the same amount of phosphorus to the soil."

Looking to the Literature

Spokas, Novak, and others conducted a meta-analysis of approximately 100 biochar studies and concluded that because of variability in char quality and application, results were about 25 percent negative, around 50 percent neutral, and around 25 percent positive. They published their findings in the *Journal of Environmental Quality.*

"A lot of research has already been done on biochar," says Spokas, who is the first author on the paper. "We're building on that work to figure out how to make biochar work best in our current production systems."

Novak, who is working with Ippolito and Spokas on additional experiments in the laboratory and field, agrees. "We just need to make sure it's the right biochar for the right soil type," he says.

"We're still trying to get our hands around this," Karlen concurs. "We're very curious. But we don't have all the answers yet."—By **Ann Perry,** ARS.

This research is part of Climate Change, Soils, and Emissions (#212) and Water Availability and Watershed Management (#211), two ARS national programs described at www.nps.ars.usda.gov.

To reach 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. ✻

Peter and the Festulolium Stalk

When Peter Pitts moved to Wisconsin in 1980 and bought a sack of grass seed, he never dreamed he'd be earning royalties from this seed's offspring becoming both a widely popular conventional grass seed and the first ryegrass in North America to be certified organic.

Having seen the virtues of ryegrass when he lived in Oregon and worked for a seed company, he wanted to plant a ryegrass pasture on the 320-acre farm he bought to raise beef cattle.

The merchant suggested festulolium (pronounced "fes-tu-lo-lium"), a ryegrass *(Lolium)* bred in Europe to contain some desirable meadow fescue *(Festuca)* genes.

Pitts planted it, and it did extraordinarily well on his mostly organic farm. After 6 years of success, Pitts visited Michael Casler, who was then a professor at the University of Wisconsin but is now a geneticist at the Agricultural Research Service's U.S. Dairy Forage Research Center in Madison, Wisconsin.

Pitts asked Casler why the university didn't recommend festulolium or ryegrass—both nutritious perennials—for pastures. Casler replied, "Because they never last more than a year."

Pitts replied, "My festulolium has lasted 6 years, despite being overgrazed and underfertilized. It has survived all those Wisconsin winters and the droughts of 1988 and 1989."

Casler couldn't believe this, so he accepted Pitts's invitation to visit his farm in Spring Green, Wisconsin, about 40 miles northwest of Madison.

Get Tough or Die

Casler and Pitts dug up some sample plants, and Casler bred them with some of the long-lived festulolium plants in old university nursery plots throughout Wisconsin. These plants represented a very small number of plants that had survived "get tough or die" conditions similar to those on Pitts's pasture.

But Casler needed supporting data before he could proceed with a formal release of the new variety. So Pitts received a U.S. Department of Agriculture small business grant and teamed up with Pure-Seed Testing, Inc., of Hubbard, Oregon, to conduct experiments to prove that the new plant was superior forage. Pure-Seed Testing's breeder, Crystal Fricker, screened the plants in Oregon for stem rust resistance, yield, and other desired characteristics. Together they documented improved freezing tolerance and persistence in the northern United States. In 1996, breeder seed of the new variety, named Spring Green, was produced.

Rose Agri-Seed, Inc., a sister company of Pure-Seed Testing, Inc., obtained exclusive marketing rights for Spring Green. The seed proved so popular that it is used throughout the world and is now sold by Land O' Lakes, Inc.—in St. Paul, Minnesota—a distributor of Rose Agri-Seed. More than a million pounds of the conventionally grown seed were sold in its first 5 years on the market. It is becoming a staple ingredient in forage seed mixes.

Spring Green Goes Green

Bill Rose of Rose Agri-Seed later had seed grown in Alberta, Canada, on land certified for organic farming. In its first few years on the market, 200,000 pounds of the organically grown seed were sold. Pitts, the University of Wisconsin, and Pure-Seed Testing, Inc., share ownership of Spring Green.

Casler calls Pitts the only farmer-grass breeder he knows. "This release would not have happened without the partnership between us and Pitts," says Casler. "This type of participatory breeding is rare in developed countries. It represents a new paradigm in the development of forage grass varieties for the United States: the direct involvement of a farmer throughout the development and marketing phases."

Casler and Pure-Seed Testing, Inc. continue to work with Spring Green in breeding new forage plants and developing better management techniques for more economically and environmentally sustainable pastures.—By **Don Comis,** ARS.

This research is part of Pasture, Forage, and Rangeland Systems, an ARS national program (#215) described at www.nps.ars.usda.gov.

Michael D. Casler is in the USDA-ARS Dairy Forage and Aquaculture Research Unit, U.S. Dairy Forage Research Center, 1925 Linden Drive West, Madison, WI 53706; (608) 890-0076, michael.casler@ars.usda.gov. ✻

Wisconsin farmer Peter Pitts (left) and ARS geneticist Michael Casler inspect festulolium ryegrass growing on Pitts's farm in Spring Green, Wisconsin.

PEGGY GREB (D2336-2)

Cleaning Cows from Inside Out

Orange peel and pulp are palatable to cattle. After ARS scientists at College Station, Texas, found that to be true, they conducted studies that show these citrus byproducts have an antimicrobial effect in the animal's gut.

Who knew? Those thick, sharp-tasting orange peels that people would never dream of eating are "snack heaven" for cows. Not only does the cow get good roughage and vitamins, but it also gets an antimicrobial boost from the peel's essential oils. That's partly because the peel contains a compound called "d-limonene," which is used in many cleaning products as an antimicrobial agent. And since adult cows can have 1 trillion or more microbes in 1 ounce of rumen fluid, there are lots to mop up!

Although experts consider the U.S. food supply to be very safe, millions of Americans become ill each year due to foodborne pathogenic bacteria. *Salmonella enterica* is a common foodborne pathogenic bacterium that is among the spectrum of microbes found inside the intestines of cattle, swine, and poultry. Transient or harmless organisms, as well as beneficial ones, are also among those intestinal microbes.

Because pathogenic *Salmonella* can be found in the live food animal, reducing its populations in the gastrointestinal tract could potentially improve food safety because fewer pathogenic bacteria would be present during slaughter and processing.

Several naturally occurring plant chemicals have shown promise as antibacterials in a variety of applications. Citrus essential oils, for example, have been part of the human diet for hundreds of years, and their effects on bacterial growth and survival are well studied. Citrus oils have been known to kill *Staphylococcus aureus, Pseudomonas, Salmonella,* and *Escherichia coli.*

An Unlikely Cleanser

A team of researchers recognized the potential of citrus byproducts as a possible food safety intervention and has been experimenting with them since 1999. The team consists of Agricultural Research Service microbiologist Todd R. Callaway and animal scientist Tom S. Edrington, with the Food and Feed Safety Research Unit in College Station, Texas; ARS animal scientist and research leader Jeffery Carroll with the Livestock Issues Research Unit in Lubbock, Texas; and John Arthington at the University of Florida in Ona. "While foodborne pathogens are found in the gut of food animals, non-antibiotic methods to reduce such pathogens in the live animal are important to improving food safety," says Callaway.

Initial laboratory results published in 2005 indicated that citrus products included in ruminant rations decreased pregastric gut and lower-gut populations of *E. coli* O157:H7 and a variant of *S. enterica, S.* Typhimurium, without causing a significant change in fermentation end products. These end products include acetate, which is a volatile fatty acid. Certain beneficial bacteria in the cow's gut produce these acids, which are absorbed by the animal to provide energy.

"Cows have evolved to depend on volatile fatty acids—or VFAs—for nearly all their energy needs," says Callaway. "Absorption of VFAs is necessary, and if there is a large disruption in VFA absorption, then there is also a disruption to the animal's efficiency, productivity, and health."

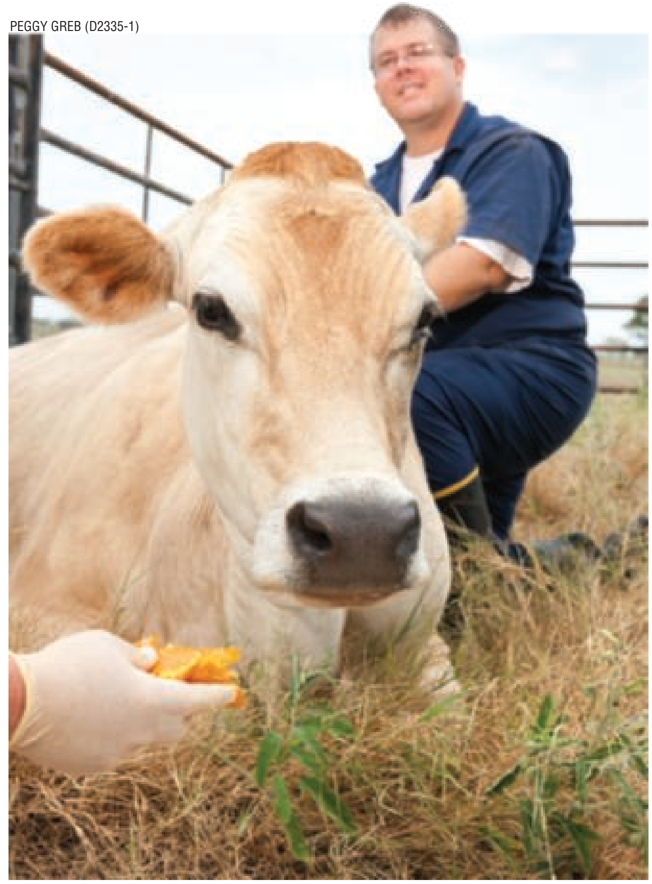
Callaway's early data showed the feasibility of using orange pulp as a feed source to provide antipathogenic activity in cattle. He also showed that citrus byproducts (orange peel and pulp) are compatible with current production practices, are palatable to the animals, and can be a "green" solution. Another plus—citrus byproducts are also economically feasible and readily available.

While citrus byproducts are fed to cattle because of their high nutritive value and low cost, Callaway has been shedding more light on how to exploit the essential oils inside the peel and pulp that are natural antimicrobials. Collaborations with University of Arkansas-Fayetteville researchers Steven Ricke and Philip Crandall have identified specific essential oils that kill pathogenic bacteria.

In other laboratory tests, Callaway's research group has demonstrated that the addition of a small amount of orange peel and pulp to a mixture of laboratory ruminal fluid fermentations reduced populations of *E. coli* O157:H7 and *S.* Typhimurium. The amount given was considered similar to a realistic amount ingested on a farm. The 2008 study, which was coauthored with Carroll, Arthington, and University of Arkansas researchers, was published in *Foodborne Pathogens and Disease*.

Callaway's further studies demonstrated that feeding orange peel and pulp reduced intestinal populations of diarrhea-causing *E. coli* in weaned swine. That study, also led by Carroll and coauthored with Callaway, was published in 2010 in the *Journal of Animal and Veterinary Advances*.

PEGGY GREB (D2335-1)



Microbiologist Todd Callaway looks on as a colleague feeds a dairy cow some orange peel and pulp. Callaway and his team have found that orange byproducts can reduce gastric populations of *Salmonella* and *E. coli* in cattle, sheep, and pigs.

From Heavy Peels to Pellets

From the time Callaway began studying citrus as an animal gut cleanser, he also recognized that citrus peel can be heavy and expensive to ship long distances. "Even as compost, citrus peels are difficult to transport," he says.

Thus, Callaway's latest studies investigated the use of processed orange peel pellets. The team fed the pellets to sheep as a model for cows for 8 days. They found a 10-fold reduction in *Salmonella* and *E. coli* O157:H7 in the animals' intestinal contents. Callaway received a grant from the National Cattlemen's Beef Association (Beef Checkoff funds) to help fund the work. These studies were accepted for publication in 2011 in the *Journal of Food Protection* and *Foodborne Pathogens and Disease*.

"When approaching preharvest food safety, we take a 'multiple-hurdle' approach," says Callaway. "These studies have the potential to lead to one more in a series of hurdles set up to prevent spread of foodborne pathogens." Processing plants, for example, depend on multiple hurdles for keeping pathogens at bay. A method of reducing the presence of pathogens in live animals before they enter processing plants could possibly be a key hurdle to add to their list.

Callaway is now preparing upcoming field trials of citrus byproducts with collaborators at ARS, the University of Arkansas, and the University of Florida.—By **Rosalie Marion Bliss,** ARS.

This research is part of Food Safety, an ARS national program (#108) described at www.nps.ars.usda.gov.

Todd R. Callaway is in the USDA-ARS Food and Feed Safety Research Unit, 2881 F&B Road, College Station, TX 77845; (979) 260-9374, todd.callaway@ars.usda.gov. ✻

PEGGY GREB (D2333-1)

Graduate student Jacquelyn Escarcha inserts samples developed from cattle fecal waste into a solution that detects *Salmonella.*

STEPHEN AUSMUS (D2320-9)

Entomologist Juan Morales-Ramos (left) and insect production worker Matthew McDaniel use a scaled-down prototype of a separator they designed to sort mealworms by size.

Coming to a

The wormlike nematodes from the genera *Heterorhabditis* and *Steinernema* are less than 1 millimeter long. But don't let their small size fool you: Both can bring down prey many times their size. People, plants, and pets aren't on the menu, though—only the larval stages of Japanese beetles, vine weevils, root borers, fungus gnats, and other insect crop pests.

Heterorhabditis and *Steinernema* species belong to a small but elite group of entomopathogenic (insect-killing) nematodes whose host-specificity has made them appealing biological alternatives to synthetic pesticides. Liquid formulations, wettable powders, and clay carriers are among products used to apply the nematodes and keep them safe during storage. About 10 years ago, however, an ARS team found that the nematodes perform best when applied to soils while still ensconced in the dead bodies of the insect hosts used to mass-produce them. (See "The Living Dead: What Lurks Inside These Insect Cadavers?" *Agricultural Research,* May 2002, p. 14.)

ARS entomologist David Shapiro-Ilan did that research with colleagues from ARS and the Virginia Polytechnic Institute and State University in Blacksburg, Virginia, and elsewhere. Shapiro-Ilan is with the Southeastern Fruit and Tree Nut Research Laboratory in Byron, Georgia.

Their approach uses the insect cadavers as a kind of staging ground from which nematodes can venture out when conditions are optimal—or at the prompting of specific chemical cues from their dead host.

Upon locating and penetrating their prey, usually via natural body cavities, the nematodes release symbiotic bacteria. They, in turn, liquefy the insect's innards, killing it in 24-48 hours. The nematodes feed on the "bacteria-seasoned" remains until all that's left is an empty shell. Within a week or two, a new generation of juvenile nematodes emerges, ready to start the cycle over again.

An Idea Takes Shape

A technical hurdle that's kept the insect-cadaver approach from gaining widespread commercial acceptance is the tendency of some commonly used host insects—notably the soft-bodied greater wax moth larvae—to rupture or stick together during storage, transport, and application.

To address this issue, Shapiro-Ilan teamed with Louis Tedders of Southeastern Insectaries, Inc., in Perry, Georgia, and entomologists Juan Morales-Ramos and Guadalupe Rojas—both with ARS's Biological Control of Pests Research Unit in Stoneville, Mississippi.

The result of that collaboration was an automated system that—in "Dr. Seuss-like fashion," as Shapiro-Ilan describes it—plucks nematode-infected insect cadavers from a container and deftly sandwiches them between two strands of masking tape. Eventually, an entire roll is formed, allowing for easy storage, transport, and application to pest-infested soils—whether in crop fields, orchards, greenhouses, or gardens.

Customized Insect-Cadaver Taping

Tedders, who had been collaborating with the ARS scientists under a cooperative research and development agreement, originally came up with the cadaver-taping idea. He also devised a prototype machine to automate the process, which Morales-Ramos and Rojas later refined to reduce labor and to standardize the final product. A patent application was filed in 2010.

Choosing the best insect species to use proved a critical early decision. Wax moth larvae had long been the nematode host of choice among insectaries and biopesticide companies, but the cadavers proved unsuitable for taping. "They become fragile and leaky; they're difficult to handle," says Morales-Ramos. Instead, the team chose mealworms, whose harder shells can withstand the rigors of carcass taping.

Using off-the-shelf parts purchased from the food-service industry, the Stoneville researchers built a prototype separation device that has blowers and customized screens to mechanically sort the mealworms by size. Previously, this had been done using hand-held screens, which was time-consuming. "Mealworms develop at different rates," says Morales-Ramos. "The biggest are chosen for nematode infection. Medium-size ones are sold for other purposes. Smaller sizes are returned to the colony to continue growing."

The mealworms are then placed in shallow plates teeming with hungry nematodes. After a few days, during which the nematodes infect and kill their hosts, a mechanical arm reaches in and places the carcasses between two strips of masking tape at the rate of one insect every 2 seconds. Future versions of the machine could speed the process by placing multiple cadavers simultaneously.

Testing Proves Tape Formulation's Worth

The next step was to test the tape-delivery system's ability to protect the cadavers from mechanical damage as well as its nematode yield and pest-control efficacy. "We found that infective juvenile nematode yield was not negatively affected by the tape formulation," says Shapiro-Ilan.

In laboratory experiments, the group measured survival of two insect pests, the root weevil or the small hive beetle, after the application of two nematode-infected hosts with or without tape in soil-filled 15-centimeter pots.

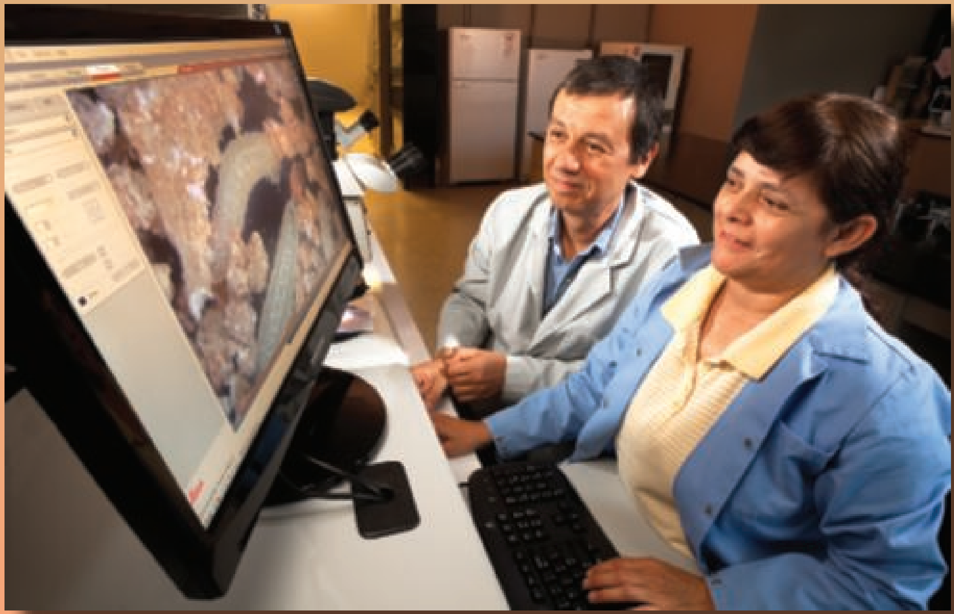
A greenhouse experiment was conducted in a similar manner to measure survival of the root weevil. "In all experiments, both the tape and no-tape treatments caused significant reductions in pest-insect survival relative to the control, and no differences were detected between the nematode treatments," says Shapiro-Ilan. "Fifteen days after application, the infected-host treatments caused up to 78-percent control of small hive beetle in the lab, 91-percent control of root weevil in the lab, and 75-percent control of root weevil in the greenhouse. These results indicate potential for using the tape-formulation approach for applying nematode-infected hosts."—By **Jan Suszkiw** and **Sharon Durham,** ARS.

This research is part of Crop Protection and Quarantine, an ARS national program (#304) 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 [Suszkiw], (301) 504-1611 [Durham], jan.suszkiw@ars.usda.gov, sharon.durham@ars.usda.gov. ✻

Inside this plump wax moth cadaver are thousands of wiggly nematodes ready to serve as biocontrols against soil-dwelling crop pests. Wax moth larvae cadavers proved too fragile for the new carcass-taping method, however, so mealworms are used instead.

PEGGY GREB (K9867-1)



STEPHEN AUSMUS (D2321-3)

Entomologists Juan Morales-Ramos and Maria Guadalupe Rojas view first-instar larvae through a microscope and evaluate the fertility of the mealworms to determine the effectiveness of diet formulations.

ANDY NYCZEPIR (D2347-1)

Tall Fescue Ground Cover Stifles Nematodes in Peach Orchards

Some tall fescues, planted and established as a groundcover before peach tree planting, can promote growth of the trees by suppressing reproduction of some species of root-knot nematodes. Here, technician Merry Bacon holds a ruler to show that trees on the left, planted into a stand of tall fescue 18 months earlier, are taller and fuller than trees on the right (controls, planted in unfumigated soils without tall fescue groundcover).

Peach growers in the southeastern United States are vexed in dealing with root-knot nematodes that can severely stunt peach tree growth. Traditionally, growers have fumigated peach orchard soils prior to planting and then used a nematode-resistant rootstock. But in recent years, growers have faced tough times that have made it difficult to afford preplant fumigants, such as Telone II or Vapam, and many growers also have difficulty with fumigating at the recommended time of year because of conflicts with managing other crops.

At a peach growers' meeting a few years ago, the question was raised as to whether a preplant ground-cover crop could be used to control nematodes instead of fumigation.

Agricultural Research Service plant pathologists Andy Nyczepir at the Southeastern Fruit and Tree Nut Research Laboratory in Byron, Georgia, and Susan Meyer at the Nematology Laboratory in Beltsville, Maryland, set out to find the answer. Their results were published in the *Journal of Nematology* in 2010.

"In Georgia, rotation with coastal Bermuda grass, which can also be harvested for hay, is recommended for control of *Meloidogyne,* or root-knot nematode," says Nyczepir. "Another potential ground-cover rotation crop for nematode management is tall fescue grass." Tall fescue is the most widely grown perennial, cool-season, turf and forage grass species, and it is well adapted in the area between the temperate northeastern and subtropical southeastern United States.

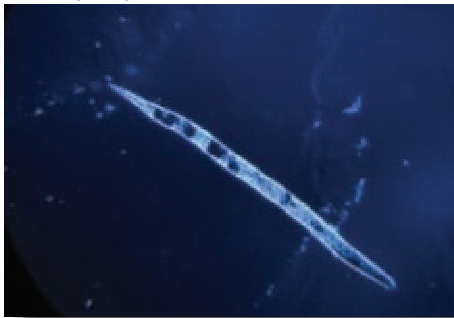
In their greenhouse studies, Nyczepir and Meyer investigated four tall fescue varieties, three of which were infected with fungal endophytes that live within the plant—typically between its cells—but do not cause disease in it.

Some Nematodes Neutralized with Tall Fescue

The four tall fescue varieties tested were a wild-type Jesup (with an ergot-producing endophyte), endophyte-free Jesup, Jesup MaxQ (with a non-ergot producing endophyte), and Georgia 5 (with an ergot-producing endophyte). Ergot is a toxic fungus that grows on rye and other grasses.

"It has been reported by other researchers that the presence of the fungal endophyte in tall fescue confers resistance to some plant-parasitic nematodes," says Nyczepir. "But the presence of an endophyte is not always beneficial; it has been associated with causing fescue toxicosis in grazing animals. Fescue toxicosis is marked by elevated body temperature, poor weight

LYNN CARTA (D2350-1)



A second-stage juvenile of the root-knot nematode *Meloidogyne incognita* (about 1/3 millimeter long).

gain, and reduced prolactin concentrations in the animals."

One way to avoid fescue toxicosis is to grow tall fescue with nontoxic strains of the fungal endophyte.

"One such endophyte-friendly commercial tall fescue variety is MaxQ," says Nyczepir. "But MaxQ's susceptibility to nematodes was unknown, so we decided to evaluate the host susceptibility of MaxQ and three other tall fescue varieties to several root-knot nematode species: *M. arenaria*, *M. hapla*, *M. incognita,* and *M. javanica*."

"Our studies demonstrated that two of the nematodes—*M. incognita* and *M. hapla*—can't reproduce on MaxQ. *Meloidogyne javanica* has a low level of reproduction on MaxQ, but *M. arenaria* can reproduce on it," says Meyer. "This shows that MaxQ may well have potential as a preplant control strategy for *M. incognita* and *M. hapla* in southeastern and northeastern U.S. areas. Using this tall fescue as a preplant cover crop treatment may allow growers to reduce the use of chemical nematicides."

"We are following up these greenhouse studies with field testing of MaxQ as an alternative to preplant chemical control of *M. incognita,*" says Nyczepir.

The team's field trials using MaxQ as a preplant cover crop have so far found that peach trees planted after the cover crop are larger than those planted in soil that is not fumigated.

"Preliminary data indicates that trees planted after a 1-year or 2-year MaxQ grass cover crop and trees planted in fumigated soil are significantly larger than trees in unfumigated soil," says Nyczepir. The peach trees that were planted after a 2-year period of growing MaxQ as a cover crop were larger than the trees planted after a 1-year period of MaxQ, indicating that the longer time had an even more beneficial effect on plant growth.

The boost in tree growth from waiting the extra year may be just what growers need. After all, as the researchers say, once a tree has been established for 3 years, damage caused by root-knot nematode is minimal, so anything that helps peach trees be healthier and stronger their first year or more is probably a good thing.—By **Sharon Durham,** ARS.

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

Andrew Nyczepir is with the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory, 21 Dunbar Rd., Byron, GA 31008; (478) 956-6438, andy.nyczepir@ars.usda.gov.

Susan Meyer is with the USDA-ARS Nematology Laboratory, 10300 Baltimore Ave., Bldg. 011A, Beltsville, MD 20705-2350; (301) 504-5091, susan.l.meyer@ars.usda.gov. ✻

PEGGY GREB (D2346-1)

Plant pathologist Susan Meyer (right) and technician Shannon Rupprecht examine greenhouse-grown tall fescue plants that will be used for studies on suppression of plant-parasitic nematodes.

Plant pathologist Andy Nyczepir studies tree height data in a peach tree establishment plot.

MERRY BACON (D2349-1)

MELISSA STEFANEK (D2329-2)

Integrated Control System Improves Cotton Health

ARS research leader Steve Naranjo (right) and University of Arizona IPM specialist Peter Ellsworth examine cotton lint for signs of whitefly honeydew. Excessive honeydew can make cotton sticky and reduce lint quality and price.

Pirate bugs, assassin bugs, and collops beetles sound dangerous, and they are. That is, if you're a sweetpotato whitefly *(Bemisia tabaci),* a common cotton pest in Arizona that is a target of those bugs and more than a dozen different predators. Steve Naranjo, an Agricultural Research Service entomologist and research leader at the USDA-ARS Arid-Land Agricultural Research Center in Maricopa, Arizona, is trying to make sure those predators and other natural enemies are well represented in that state's cotton fields.

His reason is simple. If you enhance the environment for predators of a pest, those predators will attack the pest so that you can keep insecticide use to a minimum. The concept is known as "integrated control."

"You want to foster the effects of parasitoids and predators that are already in the field, so that they work as natural controls," Naranjo says.

Historically, cotton has been plagued by dozens of pests, and in the early 1990s it was common for growers in Arizona to spray 12 or 13 times a season to control them. The arrival in 1996 of *Bt* cotton, engineered with the *Bacillus thuringiensis* gene to produce moth-killing proteins, gradually eliminated the need to spray broad-spectrum insecticides for caterpillar pests like the pink bollworm. But the *Bt* proteins did not affect sucking insects like whiteflies, making it necessary for growers to continue using broad-spectrum insecticides, which also threatened the natural biological control agents. Even when sprays were developed that specifically targeted whiteflies, some growers continued to use broad-spectrum insecticides to control them.

Over the years, Naranjo's research has explored how Arizona cotton growers can use the integrated-control approach to minimize insecticide use without affecting crop yields. His efforts, along with the introduction of *Bt* cotton and the work of other scientists, are paying off. It's now common for many Arizona cotton growers to spray no more than once a season, and in a paper published in *Pest Management Science,* Naranjo estimates that since 1995, the approach has reduced insecticide spraying in Arizona by about 70 percent and produced a net gain of more than $200 million for growers because of reduced spraying costs and increased yields.

Spray the Whiteflies, Not the Predators

Naranjo and Peter Ellsworth at the University of Arizona's Maricopa Agricultural Center conducted a 3-year study where they treated large plots with insecticides specific to whiteflies and other plots with broad-spectrum insecticides, which kill a variety of pests. They left a third set of plots as untreated controls. The goal was to find the treatment that would minimize the need for spraying by fostering activity among the whitefly predators.

The results, published in *Biological Control,* showed that whiteflies initially died off at about the same rate in areas treated with both the whitefly-specific and the broad-spectrum insecticides. But as the growing season continued, differences emerged. The area sprayed with broad-spectrum insecticides had to be repeatedly sprayed to control whiteflies, while there was no need to continue spraying the area

JACK DYKINGA (K7549-7)

STEVE NARANJO (D2319-1)

PETER ELLSWORTH (D2330-1)

Clockwise from bottom left: Whitefly cadaver (after attack by a sucking predator); a tiny pirate bug, *Orius insidiosus,* feeding on whitefly nymphs; adult assassin bug, *Zelus renardii,* feeding on a *Lygus* bug; sweetpotato whiteflies, *Bemisia tabaci,* feeding on watermelon leaf; immature assassin bug.

STEPHEN AUSMUS (D288-4)

PETER ELLSWORTH (D2332-1)

treated once with the whitefly-specific insecticide. In those areas, the whitefly's natural enemies survived the initial spraying and continued to feed on whiteflies. Naranjo and Ellsworth coined the term "bioresidual" to describe the extended environmental resistance that is possible from biological control when selective insecticides are used. Such effects were consistent throughout the 3 years of field experiments that covered 10 to 20 acres per year.

Naranjo has used the study results to develop "life tables" for whiteflies, similar to mortality tables used by life insurance companies to calculate the policy prices for their clients depending on their age, gender, and health-related habits. Scientists could use Naranjo's life-table approach to spell out how likely it is under different scenarios for whiteflies to be eaten by predators, parasitized by wasps, or blown off host plants by wind and rain.

"These results have allowed us to specifically measure the contribution of conserving the whitefly's natural enemies," says Naranjo.

Stay on the Alert After the Cantaloupe Harvest!

In other work, Naranjo and Ellsworth have uncovered evidence about whitefly feeding and migration patterns that will be helpful to growers. Whiteflies attack a wide range of crops, and one of their favorites is cantaloupe, which is grown near cotton in much of Arizona. There, cotton is planted in April and peaks in summer, and cantaloupe is harvested starting in June. In their 20-day life cycle, whiteflies move from cantaloupe fields after harvest to cotton fields and cause serious damage.

"The sudden influx of such large numbers of whiteflies to cotton overwhelms whitefly natural enemies," Naranjo says. The migration of whiteflies from cantaloupe to cotton has been a persistent problem, but growers are reluctant to switch to other crops because both are relatively profitable.

Naranjo and Ellsworth found that whiteflies typically reach excessive levels on cotton in July, coinciding with the end of the cantaloupe harvest and the passing of enough time for pest populations to grow after their initial invasion of cotton. But they found that a single application of whitefly-specific insecticides on cotton at this time preserved a sufficient supply of natural enemies and caused a "knock down" of whitefly populations to levels where those enemies could then control the whiteflies the rest of the growing season.

The results, described in *Biological Control* and *Pest Management Science,* show the benefits of using insecticides designed specifically to control whiteflies.

Naranjo also evaluates new insecticides, works with cooperative extension agents to distribute control guidelines to growers, and explores ways to use chemical attractants to increase the numbers of whitefly predators and parasitoids in cotton fields. He also is studying insecticides available to cotton growers specifically to control plant bugs, another major cotton pest.

"Our overall goal has been to encourage growers to use insecticides, if needed, that are selective. We want to arm growers with the newest and latest technology available, and as part of that focus, we're always testing new products and identifying those that are selective," says Naranjo.—By **Dennis O'Brien,** ARS.

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

Steven Naranjo is with the USDA-ARS U.S. Arid-Land Agricultural Research Center, 21881 N. Cardon Ln., Maricopa, AZ 85138; (520) 316-6333, steve.naranjo@ars.usda.gov. ✻

PEGGY GREB (D2340-1)

Research assistant Sharon Croskey (left) of Ohio State University cuts whole-grain wheat flour cookie dough for baking-quality tests as ARS technician Amy Bugaj sets baked cookies on a cooling rack.

Whole-Grain Flour Studies May Help Boost the Goodness of Crackers and Cookies

For some of us, the fun of year-end holiday gatherings isn't only the pleasure of being with friends and family.

It's also the food.

Holiday hosts seem intent on making sure that we're very well fed. Everywhere you turn, there's a snack tray laden with tasty crackers and enticing dips. Plates of sweet treats—festive cookies, for example—are often within easy reach, too.

If Agricultural Research Service wheat quality researchers have their way, more recipes for crackers, cookies, and other baked goodies will call for a greater proportion of flour made from whole-grain wheat, in relation to the amount of familiar, highly refined white flour that's used today.

"Americans don't eat enough whole grains and don't get enough dietary fiber," says wheat expert Edward J. Souza. From Souza's perspective, putting more whole-grain wheat flour into foods that people will buy and enjoy may be one way to help us get the whole grains and fiber we need.

Consumption of whole grains has, in some studies, been associated with reduced risk of cardiovascular disease, the number-one killer of Americans.

A former research leader and plant geneticist with ARS's Soft Wheat Quality Laboratory in Wooster, Ohio, Souza now directs wheat breeding for an international plant science company.

The Wheat Kernel's Three Key Components

A wheat kernel contains three key structural components: The outer, or bran, layer; the tiny wheat seed, also referred to as the "germ" or "embryo"; and the endosperm, which takes up most of the inside of a plump, ready-to-harvest kernel.

When the miller or baker wants all the grain components for a flour, the entire kernel is used. Flour that contains whole-grain components provides more fiber than traditionally milled white flours and also provides more magnesium—from the bran—which may be important for controlling diabetes and heart disease.

The bran contributes some additional minerals, including selenium, and B vitamins. The germ provides B vitamins too, along with vitamin E, small amounts of vitamins A and K, and healthful fats. The endosperm yields carbohydrates and protein.

At Wooster, Souza's research focused on soft wheat—the kind that's used for making crackers, cakes, cookies, breakfast bars, pancakes, waffles, flour tortillas, some kinds of snack chips, and more. That's in contrast to, for instance, hard wheats, which bakers choose for making loaves of raised breads, or durum flours, which chefs worldwide use for pasta.

The Wooster team's studies are filling in some of the gaps in our knowledge about whole-grain flours made from soft wheat. In recent research, for example, Souza and colleagues tackled the question of how much dietary fiber is really in today's whole-grain soft-wheat flours. In other investigations, the researchers confirmed the value of two readily available laboratory tests that can help wheat breeders predict, early on, what kinds of promising new soft-wheat plants are the most likely to yield superior whole-grain flours for cookie doughs.

Dietary Fiber: New Estimates for Bakers, Shoppers, and Nutrition Researchers

Precisely how much dietary fiber is in soft-wheat whole-grain flour isn't well known, according to Souza. "When we first began looking at information about the dietary fiber content of these flours," he says, "we found very few measurements. Some were based on surprisingly small numbers of samples. Others were based on hard wheats, not soft. And others were derived from old, outdated analytical procedures."

To help clarify this somewhat muddled picture, Souza and colleagues Mary J. Guttieri, a research specialist, and Clay H. Sneller, an associate professor, conducted what is perhaps the most comprehensive analysis to date of dietary fiber levels in a nationally representative sample of soft-wheat whole-grain flours.

Sneller is with Ohio State University's Ohio Agricultural Research and Development Center in Wooster, and Guttieri was formerly with the center.

The team used a relatively new analytical method, variously known as the "McCleary method," the "all-in-one test," and the "CODEX fiber method." They tested an impressive assortment of soft wheats from fields and flour mills across North America. For example, they acquired kernels from 13 different wheat-growing regions—from Virginia and South Carolina to Utah and Oregon—and then tested the dietary fiber levels of the whole-grain flours made from those kernels.

Approaching the sampling from another perspective, they studied five different kinds of commercial whole-grain soft-wheat flours, including some from mills in Utah and in Ontario, Canada, and from a natural foods store in Ohio.

To discover more about year-to-year variations, they compared flours from each of two different commercial wheats grown at each of two sites in Ohio during 3 consecutive years. "We wanted to take as many key factors into account as possible," notes Souza.

The scientists determined that soft-wheat whole-grain flours have, on average, about 14.8 grams of dietary fiber in each 100 grams of flour. Though that's only slightly higher than the most widely referred to U.S. estimate, it should nonetheless be of interest because of the scope of the study and the precision and accuracy of the analytical method used.

The findings were presented at the 2010 annual national meeting of the American Association of Cereal Chemists and will appear in an article accepted for *Cereal Chemistry,* a peer-reviewed journal.

Their estimate may be used in new editions of nutrition databases, sources that foodmakers may consult when preparing those nutrient data labels that you see on packaged foods. Health-conscious shoppers can check those labels in deciding which products are their best nutrition buy.

What's more, dietitians and nutrition researchers might use the data when

At the Soft Wheat Quality Laboratory in Wooster, Ohio, ARS technician Amy Bugaj (left) and research specialist Mary Guttieri, formerly with Ohio State University, grind wheat bran that will be used to prepare whole-grain wheat flour for testing.

PEGGY GREB (D2339-1)

estimating how much dietary fiber we are (or aren't) eating in America. Their analyses might, in turn, be used—along with other data from other sources—to shape future updates of the nation's dietary guidelines.

Kraft Foods North America, General Mills, Inc., and Kellogg Co. funded the research, in addition to ARS.

Tomorrow's Cookie Doughs: Which New Wheats Are Best?

The Wooster research also helps wheat breeders zero in on promising new wheat plants that might be tomorrow's superstar producers of whole-grain wheat flours for cookie doughs. "Breeders of soft wheats usually work with thousands of candidate plants every year, keeping only the best for further tryouts," according to Souza.

With research funding from ARS, Ohio State University, and Kraft Foods North America, Souza's team provided new, detailed evidence to confirm that two readily available, inexpensive, and relatively simple tests are reliable tools for getting an early, in-the-laboratory indication of how good a new wheat may prove to be as a future source of whole-grain cookie flour.

One procedure, the sucrose SRC (solvent retention capacity) test, is an indication of the flour's ability to absorb and hold water. "For cookies that are tender, not tough, you want a low SRC score," Souza notes.

In the milling softness equivalent test, quantity is the key. "The more flour produced in the first few passes through a milling device," he says, "the better the quality of the cookie."

Technician Amy Bugaj uses whole-grain wheat flour to prepare dough for the wire-cut cookie test.

PEGGY GREB (D2338-1)

The tests aren't new. They are already used at wheat quality labs across the country to evaluate candidate wheats for white-flour products. But the Wooster team's study is perhaps the most thorough examination of the two tests' reliability as an early screen for a new soft-wheat flour's performance in whole-grain cookie doughs.

"We used 14 different commercial varieties of winter-planted soft wheat for this study," comments Souza. The wheats were grown at two different locations in Ohio in 2007 and in 2008.

To prove the value of the two assays, the scientists needed to determine how closely results from those tests correlated with the whole-grain flour's performance in a more expensive—and elaborate—procedure known as the "wire-cut cookie test."

This well-established baking test gets its name from the strong, thin wire that slices the dough into cookies, readying them for big baking trays.

"We showed that breeders and food-makers can rely on the SRC and softness tests for early screening. Later, when they want to narrow their focus to only those plants that are uniquely superior sources of whole-grain cookie dough flour, they can invest in the wire-cut cookie test," Souza explains.

Of course, this phase of the research required baking dozens of cookies. The best flours make big, tender cookies, which is exactly what bakers—and millions of cookie fans everywhere—want them to do.

Souza, Guttieri, and Sneller published their findings earlier this year in a peer-reviewed article in *Crop Science*.—By **Marcia Wood,** ARS.

This research supports the USDA priority of promoting food security and is part of Quality and Utilization of Agricultural Products, an ARS national program (#306) described at www.nps.ars.usda.gov.

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

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4 research units ■ 106 employees

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8 research units ■ 535 employees

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3 research units ■ 93 employees

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Map courtesy of Tom Patterson,
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2011 INDEX

A-C

D-F

G-O

P-S

T-Z

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