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Agricultural Research

An Unsung Hero

Story on pages 12-15

SCOTT BAUER (K5052-5)

The Long-Term Agroecosystem Network

Starting Local, Going National

Farmers know their land. They know where tractors get stuck in boggy spots and how sunlight moves across the fields every day of the year. They know how to time plowing, planting, weeding, fertilizing, and harvesting to maximize the benefits of warm spells, cold snaps, winter squalls, and summer downpours. They watch for the arrival of invasive plants, insect pests, wildlife predators, and the bacteria, viruses, and fungi that create havoc for crops and livestock. And they know that how they manage their crops, animals, livestock waste, water, and soil isn't just about on-farm profits and sustainability; their actions and decisions can affect air, water, and soil resources far beyond their own fence lines.

But farmers already have their hands full with day-to-day chores and don't have much time to compare notes and discuss the costs and benefits of their management choices. And they certainly don't have the time or resources to design research protocols; instrument their fields and barns; collect air, water, and soil samples; and analyze their findings.

That's where the Agricultural Research Service—and colleagues from almost 200 other federal and state agencies, universities, and other organizations—comes in. On September 10, 2012, ARS officials announced the establishment of the Long-Term Agroecosystem Research (LTAR) network, which builds on its existing experimental watersheds and rangelands nationwide. This network addresses large-scale multi-year research; environmental management testing; and technology transfer related to the nation's agricultural ecosystems in an assortment of different environments—western rangelands, midwestern prairies, the humid southeast, the temperate Mid-Atlantic—all of which face specific regional issues and challenges linked to agricultural production.

The LTAR network is starting up with 10 sites that are already affiliated with ARS locations. These sites are at Ames, Iowa; Cheyenne, Wyoming; Columbia, Missouri; El Reno, Oklahoma; Las Cruces, New Mexico; Mandan, North Dakota; Pullman, Washington; Tifton, Georgia; Tucson, Arizona; and University Park, Pennsylvania. More locations may be added to the network in the future, including sites that can provide key data about agricultural practices in the lower Mississippi River basin, the lower Chesapeake Bay, Florida, California, and the Great Basin.

The LTAR network will use the combined information gathered at these individual locations to address complex scientific questions about long-term processes operating at regional or national scales that cannot be addressed with data from individual locations alone. Using this approach, LTAR scientists will be able to monitor agricultural issues—such as periodic outbreaks of pests and pathogens, changes in soil carbon levels, global climate change effects, and the impacts of land-use changes—in a diverse assortment of regions and environments. The data collected by LTAR teams can be used to calibrate and validate computer models that forecast how these factors play out in short-term and long-term dynamics.

Information from the LTAR network can also contribute to the development of agricultural production systems that maximize energy conservation and reduce greenhouse gases. Various forms of incentives can be investigated to encourage on-farm adoption and mitigation. These findings can also be used to optimize biodiversity for conserving and protecting natural resources and enhancing agricultural profitability.

ARS scientists working within the LTAR network interact and collaborate with researchers from other national ecological research networks, including the National Science Foundation's Long-Term Ecological Research and Critical Zone Observatory networks; the National Ecological Observatory Network (NEON), now being developed by the National Science Foundation and NEON, Inc.; and the USDA Forest Service network of experimental forests and ranges.

No matter how much we try to control our choices and manage our boundaries, our agricultural practices will leave an environmental footprint somewhere. This realization is the foundation for our work in the LTAR network. We believe our results will lead to management decisions that leave benign footprints and generate long-term sustainable systems for agricultural productivity—all of which will be essential as we protect natural resources and produce the food, feed, and fiber needed to meet the demands of an ever-expanding global population.

Mark Walbridge
ARS National Program Leader
Water Availability and
Watershed Management

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Information Staff

Editor: **Robert Sowers** (301) 504-1651
Associate Editor: **Sue Kendall** (301) 504-1623
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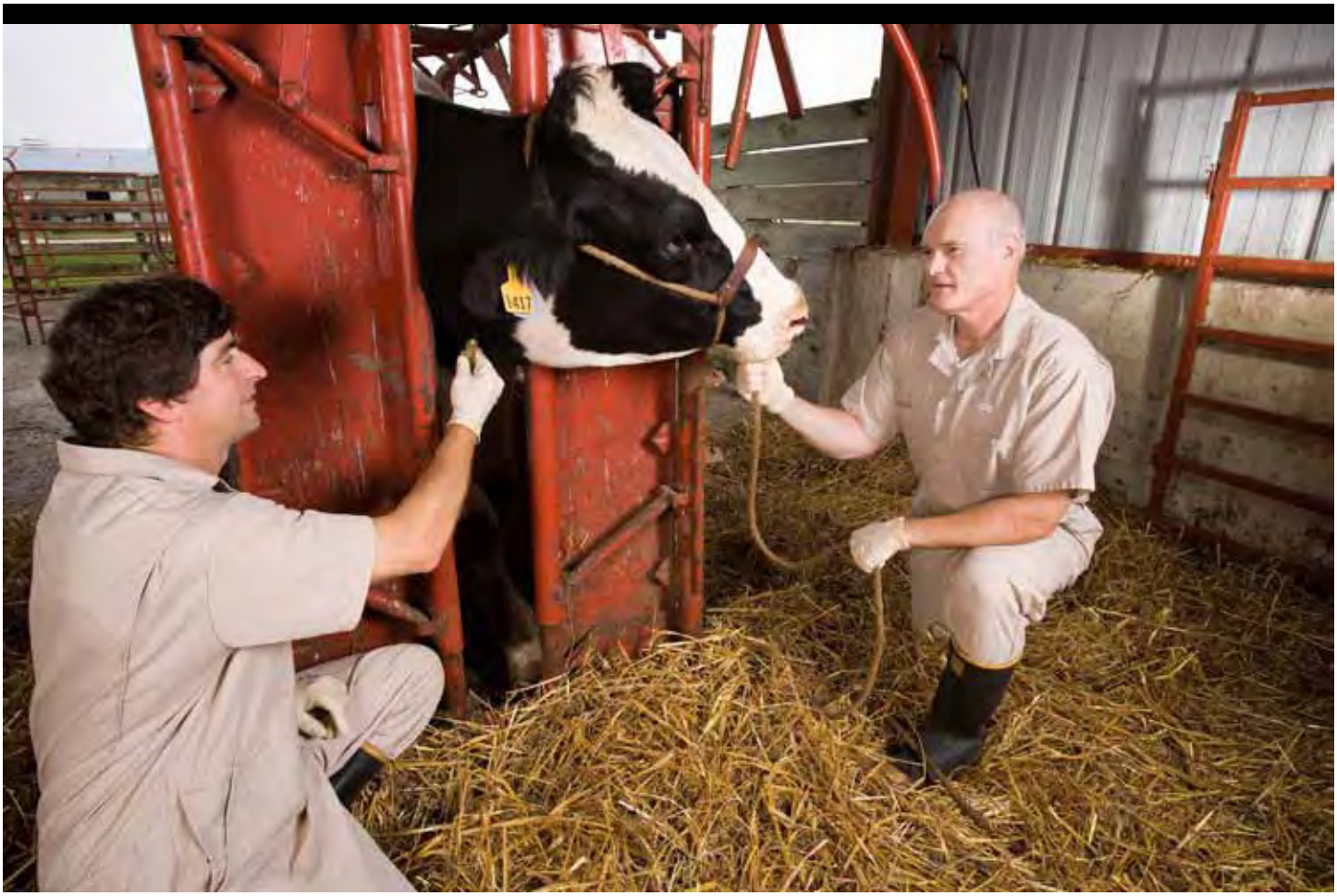
Photo Editor: **Tara Weaver-Missick** (301) 504-1663
Staff Photographers:
Peggy Greb (301) 504-1620
Stephen Ausmus (301) 504-1607

PEGGY GREB (D2958-3)

In Tifton, Georgia, technician Margie Whittle extracts herbicide residues from soil with an organic solvent. Story begins on page 10.

Cover: Artifacts relating to William Saunders, USDA's first horticulturist and superintendent of experimental gardens, including the first USDA publication, which he authored; his book starting the National Grange; medals for horticulture that he won; navel oranges which he introduced; and a Union Civil War cap and insignia. Story begins on page 12. Photo by Stephen Ausmus. (D2954-2)

PEGGY GREB (D1446-1)



Veterinary medical officers Ray Waters (left) and Mitch Palmer prepare to collect blood to be used in developing improved tests for tuberculosis in cattle. The USDA bovine tuberculosis eradication campaign began in 1917 and continues today. Tuberculin skin testing of cattle has been effective in reducing the incidence of tuberculosis in U.S. cattle, but more tools are needed for complete eradication.

Overcoming Hurdles To Eradicate Tuberculosis in Cattle

Although the prevalence of bovine tuberculosis (TB) is low in the United States, the bacterial disease can still infect cattle, wildlife, and humans. Complete eradication is not likely as long as *Mycobacterium bovis,* the causative agent of bovine TB, exists in wildlife, which can transmit the bacteria to cattle, and as long as available tests cannot accurately detect all TB-positive cattle from Mexico before they are imported.

Scientists in the Infectious Bacterial Diseases Research Unit at the Agricultural Research Service's National Animal Disease Center (NADC) are collaborating with international partners, the USDA's Animal and Plant Health Inspection Service, industry, and private companies to develop new methods to prevent and control TB in cattle and wild white-tailed deer in the United States.

Other countries with wildlife reservoirs of TB have been unable to eradicate the disease from cattle. Research to help control the disease targets wild boars in Spain, brushtail possums in New Zealand, and badgers in the Republic of Ireland and the United Kingdom.

Strategies for both U.S. and international scientists include developing and improving TB tests and finding effective methods like vaccination to stop the spread of the disease.

Widespread pasteurization of milk, development of a diagnostic tuberculin skin test for cattle, and establishment of an eradication program by the U.S. Department of Agriculture significantly helped decrease the incidence of bovine TB in humans in the United States.

Obstacles Are Skin Deep

Although the cattle skin test has helped eradication efforts, it has drawbacks.

"The test is not sensitive enough and requires a 72-hour waiting period for

results," says NADC veterinary medical officer Mitch Palmer. "It's very difficult to test a herd of 100 cows and say that this one has TB and this one doesn't, because the test may not detect one or two animals that actually have TB."

A practice called "test and remove" is an option for farmers who have herds infected with TB, but the usual method is to euthanize all animals, even if only one has TB, Palmer says. A huge push is under way to develop a better test that will help producers identify and remove infected animals and keep those that are disease free.

Interferon-gamma-release assays, used to detect TB, are whole-blood tests that require live white blood cells to work. Fresh blood samples cannot get too hot and must be processed within 8-30 hours, which means getting samples to a lab in good condition within a reasonable timeframe, says NADC veterinary medical officer Ray Waters.

Tests that require only the liquid part of the blood—the serum—would be more convenient and less expensive, Waters says.

The problem is identifying antigens that are very specific and sensitive for use in serum tests, he says. An antigen is a substance—like foreign bacteria or viruses or matter within the body—that causes the immune system to produce antibodies against it.

Contributing to New Tests

Over the last 12 years, NADC scientists have shown that improved antigens, such as one known as "MPB83," are crucial in developing effective assays, Waters says. These findings have played a key role in a new serum TB diagnostic test, developed by IDEXX Laboratories, Inc.

The test has been added to the World Organization for Animal Health registry and licensed by USDA's Center for Veterinary Biologics. It was created using IDEXX's proven enzyme-linked immunosorbent assay (ELISA) method and based on NADC's research that shows MPB83 is a useful antigen for bovine TB antibody-based tests.

"This was a team effort," Waters says. "IDEXX used samples from our experimental infection trials, and we helped the company validate and optimize the test. We then assisted with a worldwide field analysis with colleagues in the United Kingdom, New Zealand, and Ireland to verify the test's sensitivity and specificity."

"The ELISA format involves testing the animal's serum to see if it has antibodies that will react to certain components of the bacteria," Palmer says. "In addition to providing the animals, we discussed what antibodies might be best to look for, based on findings in our lab and others and on the general immune response of cattle to infection with *M. bovis*."

This test is more convenient and could potentially be used in combination with skin and interferon-gamma tests to identify undetected TB-infected animals, Waters says. "It's another tool in our diagnostic tool kit."

PEGGY GREB (K11670-2)

In addition to skin testing, mandatory milk pasteurization and the establishment of a nationwide bovine tuberculosis eradication campaign have greatly reduced the incidence of bovine tuberculosis in both cattle and humans.

The serum test is available to countries that want to add it to their list of approved eradication-program tests. Until recently, the skin and interferon-gamma tests were the only approved tests for use on U.S. cattle, Waters adds. But the United States recently approved serum tests for use with samples from deer and elephants. Both tests were manufactured by Chembio Diagnostic Systems in close collaboration with Waters and Palmer. Even more recently, the IDEXX *M. bovis* ELISA test was approved for use with samples from cattle.

Keeping It Fresh

Another type of test—based on polymerase chain reaction (PCR) analysis of DNA—has been developed by NADC microbiologist Tyler Thacker and his colleagues. The new PCR test detects *M. bovis* in fresh tissues rather than the traditionally fixed tissues prepared for viewing under a microscope. It helps distinguish between *M. bovis* and environmental mycobacteria that can cause false-positive outcomes.

"The objective was to be able to confirm *M. bovis* in fresh tissue to speed up the process," Thacker says. "That way we wouldn't have to wait potentially 2 months for the bacterium to grow."

Thacker looked at different PCR assays and discovered that many also picked up mycobacteria that were not *M. bovis*.

The scientists developed a method to eliminate the environmental mycobacteria from test results. They sequenced a region of the bacterium's DNA and developed a real-time PCR probe to help distinguish between *M. bovis* and other mycobacteria. The newly developed assay was tested against 11 mycobacterial species commonly cultured from diagnostic samples. Specificity for detecting *M. bovis* was 100 percent and sensitivity was 67 percent in samples from 30 infected and 18 uninfected animals.

"The specificity of the new PCR is the most important result," Thacker says. "The fact that it's quicker than a traditional PCR is an added benefit."

KEITH WELLER (K5176-4)

Wildlife can carry tuberculosis and spread the disease to cattle.

A Century-Old Vaccine for Deer

For more than 100 years, the Bacillus Calmette-Guerin (BCG) vaccine has proven to be safe and partially effective against TB in humans. The BCG vaccine was first tested in cows and showed protection against virulent *M. bovis*. Soon afterwards, it was used in humans and demonstrated protection against *M. tuberculosis*, the most common cause of TB in humans.

"Rather than trying to reinvent the wheel, BCG seemed like a logical choice to try with deer," Palmer says. "We're looking at its efficacy in deer. Does it actually protect them? Are there any undesirable side effects? Is it safe to use in deer that may become food for hunters?"

Today, several different strains of BCG are used to vaccinate humans in countries where TB is still a problem. But BCG is not used in the United States, because people who are vaccinated with it might test positive when given a TB skin test, even if they don't have the disease.

"The concern wasn't that BCG was going to hurt people. It doesn't produce disease or cause an infection," Palmer explains. "The concern was that if a person ate venison from deer vaccinated with BCG and subsequently had a skin test for TB, the result might be a false positive."

NADC scientists conducted studies to find out how long BCG remains in tissues of vaccinated deer. A BCG oral bait vaccine, developed by New Zealand collaborators for the brushtail possum, was fed to captive deer at a standard dose and at 10 times the standard dose. Examination of deer 1 to 12 months after vaccination showed no traces of BCG in deer given a standard dose. But BCG was detected at 12 months in deer that received the elevated dose.

"Importantly, BCG vaccine was never found in common cuts of deer meat, regardless of whether it was given orally or by subcutaneous vaccination, in any of our safety experiments," Palmer says. "We've never found it in the muscle, but only in lymph nodes and other tissues that aren't commonly used for food by humans. So it seems to be safe to use in deer."

Although the BCG bait, which resembles a hard cookie, worked well for captive deer in Iowa, it did not appeal to wild white-tailed deer in Michigan.

Palmer and his team are collaborating with scientists at USDA's National Wildlife Research Center in Fort Collins, Colorado, to develop a new bait to deliver the BCG vaccine to deer. They are experimenting with apple, acorn, and peanut butter flavors in hopes that one of these will whet the appetite of wild deer and provide an effective vaccination delivery method.—By **Sandra Avant,** ARS.

This research is part of Animal Health, an ARS national program (#103) described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Sandra Avant, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; (301) 504-1627, sandra.avant@ars.usda.gov.

PEGGY GREB (D1445-1)

Two of about 60 deer at the ARS National Animal Disease Center in Ames, Iowa. The unique research herd is used to study vaccines for prevention of tuberculosis in white-tailed deer.

The Pathways of a Shape-Shifting Pesticide

The pesticide endosulfan is being phased out in the United States because of its threat to humans and wildlife. But researchers still want to understand how endosulfan moves through the atmosphere after it has been applied to crops. Endosulfan is used against a range of insects and mites.

So Agricultural Research Service chemist Cathleen Hapeman led a 5-year study that looked at the pesticide's journey out of Florida's Homestead agricultural region. Hapeman works at the ARS Environmental Management and Byproduct Utilization Laboratory (EMBUL) in Beltsville, Maryland. EMBUL chemists Laura McConnell, Walter Schmidt, and Clifford Rice collaborated with Hapeman, along with ARS chemist Thomas Potter, who works in Tifton, Georgia.

The team established air-sampling sites in Homestead, Everglades National Park, and Biscayne National Park. The Everglades sampling site was 6 miles away from the Homestead sampling site, and the Biscayne sampling site was 12½ miles away from the Homestead site.

The researchers analyzed air samples that had been collected between 2001 and 2006 and found frequent periods characterized by significant concentrations of endosulfan in the atmosphere. Samples from all three sites were dominated by gaseous concentrations of alpha-endosulfan, the pesticide's more volatile form. Average atmospheric concentrations of alpha-endosulfan in the Homestead samples were 10 times greater than levels in the Everglades samples and 100 times greater than levels in the Biscayne samples.

Atmospheric concentrations of alpha-endosulfan and beta-endosulfan in Homestead and the Everglades were significantly higher between October and May, when pesticide applications peaked to protect the growing crops. But concentrations in the Biscayne air samples did not show as much seasonal fluctuation.

Hapeman's group used meteorological conditions to model endosulfan's atmospheric transport from Homestead. Then they compared real-time measurements of endosulfan in the Everglades and Biscayne to the model's track of the endosulfan "plume" away from Homestead under matching meteorological conditions.

The scientists observed that endosulfan levels in samples collected in the two wilderness areas rose when the model indicated that the pesticide plume had entered the sampling zones. This confirmed that when conditions are right, atmospheric levels of endosulfans can increase by drift as well as by volatilization—information that can be used to help determine the fate of the pesticide in the environment.

The scientists also made new findings about alpha-endosulfan and beta-endosulfan, which are mixed and applied to crop fields at a 7:3 ratio. Both forms have the same chemical composition, but their geometry at the molecular level is different. Results from previous studies had suggested that beta-endosulfan degraded fairly easily, since it was usually found at such low levels in the environment.

But Hapeman's group found the molecular geometry of beta-endosulfan could easily change into the molecular geometry of alpha-endosulfan—a process called "isomerization"—which explains why beta-endosulfan was detected much less frequently during atmospheric sampling. Alpha-endosulfan volatilizes more easily than beta-endosulfan, which in turns facilitates its atmospheric transport far away from its point of origin.

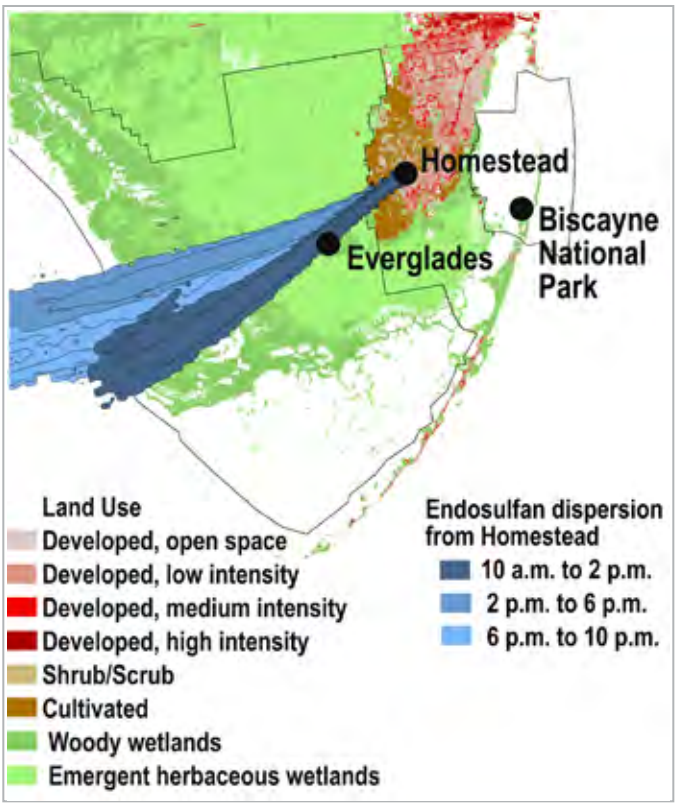
"This gives us a clearer picture of how both compounds have actually moved through the environment when they've been used in crop management," says Hapeman.

The scientists published their findings in a 2012 issue of *Atmospheric Environment*.—By **Ann Perry,** ARS.

This research is part of Climate Change, Soils, and Emissions, an ARS national program (#212) described at www.nps.ars.usda.gov.

*Cathleen Hapeman is with the USDA-ARS Environmental Management and Byproduct Utilization Laboratory, 10300 Baltimore Ave., Beltsville, MD 20705-5128; (301) 504-6451, cathleen.hapeman@ars.usda.gov.**

ARS researchers tracked how endosulfan moved through the atmosphere after the pesticide was applied to crop fields in Homestead, Florida, and used this information to create endosulfan dispersion models (below). They found significant seasonal fluctuations in the atmospheric concentrations of endosulfan in Homestead and the Everglades, but did not observe similar patterns in Biscayne National Park.



LAURA MCCONNELL (D2983-1)

ELIZABETH DRAKE (D2988-1)

Understanding and Controlling Two Invasive Vines

Entomologist Lindsey Milbrath (left) and biologist Jeromy Biazzo examine a pale swallowwort plant in a research plot.

JEROMY BIAZZO (D2990-1)

JEROMY BIAZZO (D2987-1)

Top: Pale swallowwort has reddish flowers.

Directly above: Black swallowwort has dark-purple flowers. Both species are invasive in the Northeast.

Even the name sounds threatening. Known as "dog-strangling vines" in Canada, European swallowworts are invasive vines that can grow to 8 feet in length and wrap around supporting vegetation and smother it. There are two species, pale swallowwort *(Vincetoxicum rossicum)* and black swallowwort *(V. nigrum),* and both will colonize disturbed soils and infest nurseries.

Both species have pushed onto pastures and are encroaching on the habitats of threatened and endangered species in New England and New York and of distinctive, prairie-like vegetation around the Great Lakes. Pale swallowwort also may harm forest regeneration. Both have been in the United States since the 1800s but have been expanding rapidly since the 1970s and are now found in Canada and at least 21 states from New England to Maryland and west to Kansas and Nebraska.

Lindsey Milbrath, an Agricultural Research Service entomologist with the Biological Integrated Pest Management Research Unit in Ithaca, New York, is working with ARS and university colleagues in Ithaca; Urbana, Illinois; and Fort Detrick, Maryland, and with partners overseas to try to curb the threat these two weed species pose to nurseries, Christmas tree farms, pastures, and natural areas.

The researchers are evaluating several potential biocontrols and searching for the biological mechanisms that make European swallowworts such dogged threats. "We're looking for weak links that we could somehow exploit to control them," Milbrath says.

Why Are They So Successful?

Research has shown that the reddish-flowered pale swallowwort grows rapidly in fields and forest edges but also invades understories, whereas the purple-flowered black swallowwort prefers habitats with more daylight. Pale swallowwort is from Russia and Ukraine, and black swallowwort is from southwestern Europe. Both have tenacious roots and buds that send out new shoots when surface growth is pulled up or mowed.

Hatchlings of the moth *Abrostola clarissa,* a potential biocontrol agent, feeding on a pale swallowwort leaf.

JEROMY BIAZZO (D2985-1)

Mature larva of the moth *Abrostola clarissa.*

In one study, the researchers identified a mechanism that swallowworts might be using to colonize an area. Previous research suggested that pale swallowworts might be putting phytotoxins into the soil to discourage the growth of competing plants nearby—a process known as "allelopathy." But the specific compounds responsible for pale swallowwort's toxic effects had not been identified. The researchers wanted to determine whether both swallowwort species use a similar allelopathic strategy in displacing native plants.

Plant physiologist Donna Gibson and her colleagues at the ARS unit at Ithaca analyzed extracts from roots, leaves, seeds, and shoots from pale and black swallowworts. Their previous work showed that the roots of pale swallowwort contain antofine, a compound believed to have some antifungal, antibacterial, and cytotoxic properties. With the help of high-performance liquid chromatography, they found that both pale and black swallowworts contain antofine not only in roots, but also in shoots, leaves, and seeds. The results suggest that antofine may be one key to the vines' ability to colonize an area.

In further experiments, they exposed lettuce seedlings to a variety of swallowwort extracts and found that one of the extracts, which contained antofine, inhibited growth of lettuce roots. They subsequently found that antofine strongly inhibited growth of three plants known to share swallowwort habitat in North America—common milkweed, butterfly milkweed, and Indianhemp—while having no effect on either swallowwort. The effects were not as pronounced for extracts made from black swallowwort, which generally contained lower concentrations of antofine. Results were published in the *Journal of Chemical Ecology* (2011).

The Search for Biocontrols

In their native ranges, European swallowworts are kept in check by natural enemies, particularly insects and diseases. So far, nothing in North America has halted their advance, and while eradication is no longer feasible, the researchers hope to find a biocontrol to reduce swallowwort populations.

"Even with a highly successful program, the plant will always be around, just at a much lower density. Eradication is only feasible with a small, localized infestation," Milbrath says.

The scientists have narrowed down the list of potential biocontrols from more than nine original candidates to four—two fungi and two moths that, as caterpillars, feed on related species of swallowworts. One of the moths, *Abrostola clarissa,* was found in Russia with help from collaborators at the Zoological Institute of the Russian Academy of Sciences in St. Petersburg. The other moth, *A. asclepiadis,* was collected in France with help from collaborators at the ARS European Biological Control Laboratory in Montpellier. The moths are currently the focus of continuing studies by Milbrath and by scientists overseas. Among the challenges facing scientists is breeding disease-free moths for further testing.

"We need to have moths that are pathogen free to properly understand what plants they will or won't feed on. A diseased moth may not behave normally," Milbrath says.

One of the fungi being evaluated was found by a park naturalist in rural Monroe County, New York, who noticed an unusual dying off of a pale swallowwort population. The naturalist contacted Gibson, who collected samples and cultured them in her laboratory. By comparing its DNA with known samples, she identified it as *Sclerotium rolfsii.* She and her colleagues then used the fungus to inoculate sterilized seedlings of black and pale swallowwort in growth chambers.

"It shows promise, but we need to do more research to evaluate the host range of this isolate before we could consider the possibility of its use," Gibson says. Results were reported in *Plant Disease* (2012).

The other fungus, *Colletotrichum lineola,* was found on a related species of swallowwort, *V. scandens,* in Russia. ARS plant pathologist Dana Berner, who discovered it with help from his Russian partners, brought it back under quarantine conditions to the ARS Foreign Disease-Weed Science Research Unit, in Fort Detrick, which is equipped with a secure BSL-3 containment facility that prevents the escape of any pathogens being evaluated. In a preliminary study, he cultured the fungus and used it to successfully inoculate seedlings of *V. scandens,* along with seedlings of black and pale swallowworts, under controlled conditions. After growing for 2 weeks in a quarantined greenhouse, all three swallowwort species developed symptomatic dark-red and purple spots on their leaves. Berner reported his findings in *Plant Disease* (2011).

Before any biocontrol can be released, however, it must undergo extensive testing and clear a number of regulatory hurdles designed to protect the plants that share the swallowworts' habitats in North America. That process can take several years. But Milbrath is confident that the efforts will pay off and that researchers will find a way to reduce the threat that the two European swallowworts pose to agriculture and wildlife habitats.—**Dennis O'Brien,** 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 Dennis O'Brien, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; (301) 504-1624, dennis.obrien@ars.usda.gov.

Fighting Back Against Glyphosate Resistance

ROD PENTICO (D2992-1)

In Fort Collins, Colorado, plant physiologist Dale Shaner uses a dye test to detect the compound shikimate in plant leaves. Measuring this compound can determine whether a weed will resist the herbicide glyphosate.

Below: Tubes with blue color tested positive for shikimate, and the clear liquid was a negative result.

ROD PENTICO (D2993-1)

Success sometimes comes with a price.

The herbicide glyphosate is highly effective at controlling a broad spectrum of weeds in gardens and on farms. It has been sold for many years in products known commercially as "Roundup" and is used with conventional crops and with varieties of corn, cotton, soybeans, and canola that were developed specifically to withstand glyphosate.

Glyphosate use also has environmental benefits, such as simplifying weed control in reduced-tillage farming. It has allowed growers to switch from conventional tillage practices to no-till systems that reduce labor costs, improve soil quality, and help curb soil erosion. About 93 percent of soybeans, 78 percent of upland cotton, and 70 percent of corn produced in the United States in 2010 were glyphosate-tolerant varieties.

Glyphosate's popularity, and the common practice of using it with no other herbicides, has led to the emergence of a dozen glyphosate-resistant weeds. Growers who stop using glyphosate often go back to tilling their soil, reversing the improvements in soil quality seen over the past decade.

"Widespread use of glyphosate, often to the exclusion of other herbicides, ensured that weeds capable of surviving glyphosate would thrive. Now that we're seeing that happen, we need to address it," says Dale Shaner, a plant physiologist who recently retired from the Agricultural Research Service Water Management Research Unit, in Fort Collins, Colorado.

Shaner is working as a collaborator with Monsanto to develop a kit that growers could use to determine whether weeds in their fields are glyphosate resistant. Thomas Potter, an environmental chemist at the ARS Southeast Watershed Research Laboratory in Tifton, Georgia, is evaluating an herbicide that some cotton growers are using as an alternative.

Value of Early Detection

One key to addressing the threat posed by glyphosate resistance is early detection.

"If resistant weeds are detected early, you can minimize the problem by either using another herbicide or, in the case of palmer amaranth, one of the most difficult weeds to control, getting into the field to pull it out." Shaner says.

Scientists can determine whether a weed will resist glyphosate by measuring the amount of a compound known as "shikimate" in its tissues. Glyphosate kills weeds by interfering with production of aromatic amino acids, and shikimate plays a key role in producing those amino acids. It is the "shikimate pathway" that glyphosate disrupts, causing shikimate to accumulate. Plants susceptible to glyphosate will have high levels of shikimate, while resistant plants will not.

Existing methods for detecting shikimate in plants require sophisticated laboratory equipment, such as spectrophotometers that can measure ultraviolet light. Test results can take weeks.

Now, Monsanto has developed a method for detecting shikimate in just 24 hours, using a dye that changes color. Shaner plans to help Monsanto fine-tune the technology so that it's ready for use nationwide.

Weed management is a key part of the research conducted at the Water Management Research Unit.

"We study how best to ensure high yields with limited water, and critical to managing water is managing weeds. You want a weed-free field for your crop

In Tifton, Georgia, technician Sally Belflower loads soil sample extracts into an autosampler of a gas chromatograph-mass spectrometer to test for herbicide residues.

PEGGY GREB (D2959-1)

so there's less competition for available water," Shaner says.

As part of his work with Monsanto, Shaner is growing glyphosate-resistant and glyphosate-susceptible crops and weeds in a greenhouse. He will spray some of those plants with glyphosate and place leaves from others in glyphosate solutions and then determine the levels and rates of shikimate accumulation. The goal is to evaluate different methods for assessing shikimate levels and to determine the most effective way for growers to collect plant material for testing with Monsanto's system. The test kit's design has yet to be determined.

Looking at Other Alternatives

Soybean growers in Georgia have been using the herbicide fomesafen for years, and now with weeds developing glyphosate resistance, cotton growers have been using it as an alternative. It was approved for use on cotton in 2008 after glyphosate-resistant forms of palmer amaranth were discovered in the region. But concerns about potential adverse environmental impacts were noted at the time, particularly its effects on runoff into surface water. Growers also needed more information on how to use it when practicing conservation tillage.

Cotton growers in the region often rotate cotton with peanuts and either conventionally till the soil or use a common conservation practice, strip tillage. When they strip till, they typically use rye as a cover crop, spraying it with an herbicide in March or April to kill it. The dead ryegrass provides a mulch cover for the fields. When herbicides like fomesafen are sprayed, the mulch can intercept the chemical and prevent it from reaching the soil where it will be most effective. Herbicides intercepted by mulch can also damage cotton crops if they wash off after the cotton germinates.

Potter and colleagues evaluated how well a conservation practice known as "irrigation incorporation" would wash the herbicide off the mulch and move it into the soil, reducing the potential for crop injury and excessive runoff. Irrigation incorporation involves irrigating a few days after applying an herbicide. The practice greatly enhances weed control by improving herbicide contact with germinating weeds.

They divided a field of cotton equally between strip tillage and conventional tillage. In the strip tillage section, they planted rye as a cover crop. Fomesafen was applied to the whole field, and irrigation incorporation was used on half of it. They then applied simulated rainfall and diverted runoff into troughs at the lower end of the fields for analysis. The rye crop residue was also collected and analyzed.

The results, published in the *Journal of Agricultural and Food Chemistry* (2011), showed that fomesafen is more likely than other herbicides to wash off surface residue and penetrate into the soil as desired. Fomesafen's "wash-off rate" was much higher than that of other herbicides studied. The results demonstrated the benefits of using irrigation incorporation with fomesafen, particularly when conservation tillage is practiced. The product's high wash-off rate means that by applying a small amount of irrigation after the herbicide is applied, most of it will move into the soil, where it will not damage the cotton and will be most effective at controlling weeds. The results also showed that irrigation incorporation substantially reduces runoff of fomesafen and minimizes the potential for adverse water-quality impacts.

The results will help growers concerned about glyphosate resistance make better-informed decisions about herbicide alternatives.—By **Dennis O'Brien,** ARS.

This research is part of Water Availability and Watershed Management, an ARS national program (#211) 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 20705-5128; (301) 504-1624, dennis.obrien@ars.usda.gov.

Environmental chemist Thomas Potter examines cotton plants in an herbicide-treated field in Tifton, Georgia. He is studying how different herbicides behave when used with conservation tillage to determine the best combination for cotton farmers.

PEGGY GREB (D2957-2)

William Saunders

A Monumental

USDA (D2955-1)

William Saunders (above) made monumental contributions as the first USDA horticulturist and superintendent of experimental gardens from 1862-1900, where he, "more than any other official connected with the early history of the Department of Agriculture . . . believed in and contributed to its usefulness," wrote Frank L. Evans, chief, Divisions of Accounts, circa 1906, in an unpublished reminiscence, now part of the National Agricultural Library Special Collections. In addition, in 1867, Saunders helped found and was the first president of the National Grange, the oldest American agricultural advocacy group with a national scope.

One hundred and fifty years ago, on November 19, 1863, President Abraham Lincoln delivered what would come to be known simply as the "Gettysburg Address" at the dedication of the Gettysburg battlefield cemetery.

Doesn't sound like an agricultural story, does it?

But it was William Saunders, the first horticulturist and superintendent of experimental gardens with the newly created U.S. Department of Agriculture, whom President Lincoln called on to fashion a national cemetery at Gettysburg, one to be unlike any preceding monument for the fallen.

What Saunders created was a revolution in battlefield cemeteries. He used a simple radial configuration grouping Union dead by state (Confederate bodies were returned to their home states), with each grave marked by a flat, gray, granite rectangle. Surrounding the graves, Saunders created an extensive planting plan to frame the site's vistas, specifying uncommon choices of trees and shrubs. Many of the trees and shrubs were those recently introduced to this country by Saunders himself.

This combination—no grand headstones or sculptures and extensive green landscaping—was unique, never previously seen in either Europe or the United States.

At President Lincoln's request, Saunders spent an evening at the White House presenting his proposed design. The President heartily approved.

"He [Lincoln] was much pleased with the method of the graves, saying it differed from the ordinary cemetery, and after I had explained the reasons, said it was an admirable and befitting arrangement," Saunders recounted in a historical journal that is part of the National Agricultural Library (NAL) Special Collections. The library is part of USDA's Agricultural Research Service.

In addition to what was to become the Soldiers' National Cemetery at Gettysburg, Saunders went on to design the landscaping for Lincoln's tomb, the west façade of the Capitol, and many other important locations. While still the USDA superintendent of experimental gardens, Saunders became president of the Washington, D.C., Parking Commission, where he developed a system of parks and street tree plantings that became an enduring foundation for the city's reputation as the "City of Trees." He oversaw the planting of 80,000 trees in Washington, D.C.

Introducing New Plants

But Saunders did far more for the country than design landscaping. He also

USDA (D3010-1)

In the 1860s, some top agricultural services in existence today were started. Examples include establishment of a national agricultural library, a plant and animal introduction program, and the gathering of national agricultural statistics. Saunders (second from left in this 1867 photo) and other high-ranking officials were part of the supporting cast of first Commissioner of Agriculture, Isaac Newton (fifth from left), who took the helm in efforts to create these services.

Figure in USDA

(D2968-1)

Saunders's original design for Soldiers' Cemetery at Gettysburg, Pennsylvania.

(D2974-1)

Image courtesy of Pennsylvania Department of Conservation and Natural Resources.

NASA satellite image of Soldiers' Cemetery today.

introduced hundreds of economically important plants, including Japanese persimmon; *Eucalyptus globulus* tree; Japanese cedar *(Cryptomeria japonica)*; 300 varieties of winter-hardy apples from Russia that had a profound effect on the Northeast's apple growing; camphor tree; one of the first magnolia trees in Washington D.C.; and many more.

USDA (D2972-1)

If you had to pick out a single plant introduction as Saunders's legacy, it would be the Washington navel orange. According to the 1937 "USDA Yearbook of Agriculture," introduction of the Washington navel orange was considered "one of the outstanding events in the economic and social development of California."

Saunders introduced the navel orange that gave rise to a California industry. Left: One of the original two navel orange trees, circa 1920s. Middle: A navel orange crate label memorializing the same tree. Right: The same tree still produces fruit today.

(D2978-1)

In "A History of the Parent Washington Navel Orange Tree," Chester N. Roistacher wrote: "This new, large, sweet and seedless fruit was a marvel to see and taste in contrast to the small and seedy fruit on the existing seedling trees then present in California. The arrival of this new variety, so excellently adapted to the climate of California, was largely responsible for the development of many new cities, fruit packing houses, inventions in boxing machines, fruit wraps, and the iced railroad car."

In his journal, Saunders described how he brought about the introduction: "Sometime in 1869, the then Commissioner of

KEVIN KIDDER (D2970-1)

USDA-NAL (D2956-1)

Saunders organized USDA's first publication, a catalog from the U.S. Propagating Garden, including an entry for the camphor tree, one of many plants he introduced into this country.

Agriculture, Horace Capron, brought to my attention a letter which he had just received from a correspondent in Bahia, Brazil. Among other matters, special mention was made of a fine seedless orange of large size and fine flavor. Thinking that it might be of value in this country, I noted the address of the writer and sent a letter asking to be the recipient of a few plants of this orange. This request brought, in course of time, a small box of orange twigs, utterly dry and useless. I immediately sent a letter requesting that someone be employed to graft a few trees on young stocks and that all expenses would be paid by the Department. Ultimately a box arrived containing 12 newly budded trees and, being packed as I had suggested, were in fairly good condition."

Eventually, in 1873, Saunders presented two of the navel orange trees, which he was calling the "Bahia navel," to an old friend, Eliza Tibbets, who was moving from Washington, D.C., to join her husband in the new community of Riverside, California.

Tibbets had contacted Saunders for suggestions of a crop that would prosper in Riverside's arid, Mediterranean climate. Riverside's early settlers needed to find a crop that would do well in their dry and dusty environment to ensure the town's survival. Various other crops had had only moderate success.

The navel orange was an immediate success and quickly spread to other parts of California. Luther Holt, publisher of the *Riverside Press and Horticulturist,* called it the "Riverside navel." But cities around Riverside objected to that name, and eventually it was changed to the "Washington navel," in honor of the source city—or perhaps our first president.

Because the Washington navel orange is seedless, all of its many, many descendants are grafts from those original two trees. One of those trees, planted in downtown Riverside and now more than 140 years old, is alive and healthy.

"It promises glorious results in the near future, from which the 'lords of the soil' will be directly and largely benefited and the national wealth increased."

The New York Times
April 26, 1873

But far broader in impact than Saunders's individual introductions, even as important as many of them have been, was his codifying of the mission of the USDA Experimental Gardens, which he headed from his initial appointment in 1862 until his death in 1900. These guidelines were presented in his "Catalogue of the Plants, Bulbs, Tubers, Etc., for Distribution from the U.S. Propagating Garden with a Report on the Objectives and Aims of the Garden." Dated 1862, this catalog,

USDA (D2969-1)

ROBERT GRIESBACH (D3013-1)

Left: Saunders specified the planting of two lines of ginkgo trees, then a largely unknown landscape choice, to adorn the original USDA building in Washington, D.C., circa 1870.

Above: One of the two ginkgos remaining today, almost 150 years later.

with the guidelines, was USDA's very first publication. It is available in NAL's Special Collections.

The guidelines called for USDA to not only procure new and better plants for the country, but also to "ascertain, by experiment, the influences of varied culture" and "to investigate more thoroughly the various maladies and diseases of plants and the insects that destroy them."

That "by experiment" was Saunders's most significant contribution. He originated the standard for systematic evaluation and reporting about the characteristics of the thousands of new plants being introduced into the United States, explains ARS Deputy Assistant Administrator Robert Griesbach. ARS is the USDA agency that has inherited the Department's germplasm collecting-and-preservation mission.

"What William Saunders did was set out that all of the important traits of a variety should be evaluated at the same time and under several sets of growing conditions," Griesbach says. "That sounds so obvious now, but before Saunders, evaluations were really just hit or miss. Rarely was an effort made to gather all the information and publish in one place. Most of the work was published by gentleman farmers and amateur plant breeders, who were often only interested in a single trait."

For instance, in just 2 years, from 1865 to 1867, the USDA Experimental Farm was used to evaluate and propagate more than 120 wheats, 167 ryes, 230 melon varieties, 70 peas, 50 grass species for hay production, and more than 500 strawberries, grapes, apples, and pears. That information was published and made available to farmers.

"The precedent that Saunders set has had a profound effect, right down to the way we work today," Griesbach adds.

Tappahannock wheat is a typical example. Beginning in 1866, it was identified in the evaluation program as a superior wheat cultivar, noted for its high yields, early maturity, disease resistance, and flour quality. Saunders distributed the wheat to farmers in many locations and requested that each report back on the traits and success of Tappahannock. His correspondence demonstrated that the cultivar was widely adapted to many regions of the country, from New England to the lower South and through the Midwest.

A report from Giles County, Tennessee, to USDA stated that Tappahannock wheat "sown the 10th of October, ripened two weeks earlier than other varieties and yielded one-fourth more of excellent wheat." Braxum County, West Virginia, reported similarly, adding that "it was free from rust and the weevil." These are just two of the extensive reportings Saunders collected and made available in the "Report of the Commissioner of Agriculture for the Year 1868."

Even the *New York Times* recognized the importance of collecting, evaluating, and distributing information about new varieties. In an article published April 26, 1873, it cited the "wheat crop in 1862… average yield per acre was 12.1 bushels. With Tappahannock, wheat distributed by the department showed an average yield per acre of twenty-five bushels."

The article went on to conclude that "such are some of the objects and achievements of the Farmers' Department of the Government. It has only now [1873] entered fairly upon its work of advancing agricultural science and elevating agricultural industry. But it promises glorious results in the near future, from which the 'lords of the soil' will be directly and largely benefited and the national wealth increased."

There is no question this prediction has come true. Today, U.S. agriculture provides the people of this country with a bountiful low-cost diet, and in 2012, U.S. agricultural exports totaled more than $141 billion.

When Saunders died in 1900, USDA statistician John Hyde was quoted in the *New York Times* obituary as saying that "the department has not begun to exhaust the suggestions of value made by Mr. Saunders."—By **J. Kim Kaplan,** ARS.

For information about the materials or people mentioned in this article, contact Kim Kaplan, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; (301) 504-1637, kim.kaplan@ars.usda.gov.

(D2977-1)

A navel orange crate label, now considered collectible art. This one is from Sunkist and features Abraham Lincoln.

STEPHEN AUSMUS (D2976-15)

Saunders played an instrumental role in the creation of the U.S. National Arboretum. Here, ARS Deputy Assistant Administrator Robert Griesbach takes a look at one of the many plant specimens inside the herbarium at the Arboretum.

Multiple Prospects for Maine's Potato Producers

Given all the pathogens that can create havoc in a potato field, it's a wonder spud production can keep up with demand. Producers need to control these microbes with cost-efficient management strategies that also promote soil quality and farm profits.

"Potato production is a tillage-intensive system that's very hard on soils," says plant pathologist Bob Larkin.

At the New England Plant, Soil, and Water Research Laboratory in Orono, Maine, Larkin and his colleagues have been conducting studies that investigate potato production from almost every angle they can find. Their results have been published in almost a dozen papers and provide valuable guidance to farmers who want to keep Maine among the top 10 states in potato production.

"We're looking for improvements we can obtain through cultural practices," says Larkin. "We started with different crop-management practices, like using different rotations and cover crops with potato, and adding disease-suppressive crops and soil amendments. Then we tested different practices within the cropping systems. Each practice may have a small but significant effect, so we want to see how we can combine them to obtain multiple strategies that provide cumulative beneficial effects."

Larkin had three clear objectives in mind—reducing disease, increasing yields, and increasing production sustainability—and he knew that no single practice could accomplish all three goals. So he began working with Orono agricultural economist John Halloran and others to test strategies using cover crops, rotation schedules, soil amendments, and irrigation.

Potato Patches in Progress

In one study, the scientists investigated how eight different 3-year cropping systems, which included potato as the third crop in the rotation, affected soil microbes. In another study, the scientists examined how "green manure"—that is, a cover crop that is plowed into the soil—affected the activity of soilborne potato pathogens. In a third study, the team examined how assorted biological amendments affected beneficial soil microorganisms and reduced soilborne potato diseases. The amendments included commercial biocontrol agents, microbial inoculants, mycorrhizae, and aerobic compost tea.

Larkin's team included some of this work as a component of another 10-year study to see how seven different 2-year rotations affected the development of soilborne potato diseases, tuber yield, and soil microbial communities. The team also assessed the effects of these same rotations with and without a fall cover crop of no-till winter rye over a 4-year period.

Plant pathologist Bob Larkin examines a potato field for disease.

JIM HUNT (D2991-1)

From the extensive data they gathered in the studies, the scientists developed some very clear recommendations for Maine potato producers.

"In general, 3-year crop rotations, as opposed to the 2-year rotations typically used, help break the host-pathogen cycle," says Larkin. "We found that 3-year rotations provide better disease control and higher crop yields. These rotations also help support beneficial soil microbes that improve soil quality by increasing soil organic matter or by inhibiting plant pathogens."

Larkin's team has looked extensively at potential disease-suppressive rotation crops, such as *Brassica* (canola, rapeseed, and mustard) and sudangrass cover crops. The scientists observed that in general, using mustard as a green manure reduced the incidence of powdery scab, common scab, and *Verticillium* wilt most consistently. They noted that *Brassica* cover crops planted in the fall prior to spring potato planting reduced the incidence and severity of black scurf on tubers by 30 to 80 percent and reduced the incidence of common scab up to 50 percent. Rapeseed provided the highest reductions in black scurf.

"Given these results, we think that farmers can inhibit pathogens that cause soilborne potato diseases by planting a *Brassica* green manure crop like mustard or rapeseed," Larkin says. "In Maine, this would be a late summer or early fall crop that is plowed under while it was still green, and then potatoes could be planted the following spring. A fall cover crop can also help conserve the soil."

The Rain in Maine

For Maine potatoes, adequate soil water levels are especially crucial in mid-August, when underground tubers are bulking up—and when rainfall levels are declining. Some farmers have started to irrigate their crops during this time to increase yields. But Larkin observed that organic amendments, like a compost blend, boosted yields almost as much as irrigation because the amendments improved the retention of soil water that could be used by the maturing potatoes.

After weighing the costs and benefits of different management systems, Larkin concluded that using a combination of *Brassica* and sudangrass green manures, fall cover crops, and crop rotations can reduce soilborne diseases by up to 58 percent—and adding compost to the mix increases tuber yields up to 42 percent.

WAYNE HONEYCUTT (D2984-1)

Cropping systems trial in Presque Isle, Maine, representing different soil and crop management goals. Pictured crops include potato, barley, rapeseed, mustard, and sudangrass.

"We also know it's important to be able to offer different options to Maine farmers," Larkin says. "Potato is the main cash crop, but farmers using a 3-year rotation need another cash crop as well—maybe corn or beans or canola. The second crop may not be as profitable as potato, but it does provide some income."

Larkin is now investigating how different cropping practices affect soil microbial communities and ecology, information he'll use to develop soil systems that actively suppress crop diseases.

"If we can use soil microbial communities to develop disease-suppressive soils, then we can establish sustainable disease-suppressive systems," he says. "We need to start by identifying specific organisms and processes that suppress disease."

Larkin's group also used mapping programs to study cropland data obtained via remote sensing and soil data sets and determined that an estimated 153,000 acres of state farmland were used for potato production. They also noted that 85 percent of this acreage had soils that were classified as potentially highly erodible or highly erodible, which highlighted the need for crop management that includes soil conservation strategies.

Fortunately, interpretations of the remotely sensed crop data also indicated that farmers are shifting to longer crop rotations that intersperse small grains with potato. This in turn can help restore soil quality, which has been decreasing over the years because of continuous potato production.

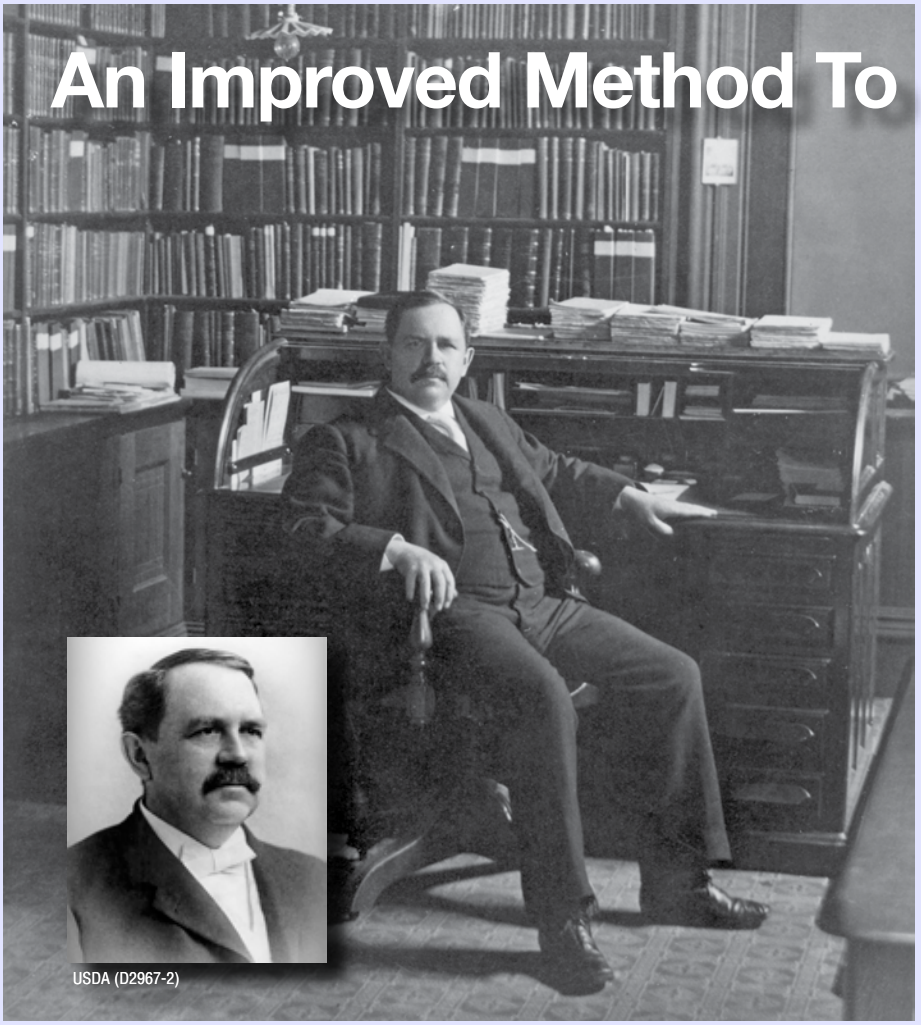
"This gives us a snapshot of what growers are doing, what production systems are being used, and what soils are being used," Larkin says. "It helps us identify where the problems are and what direction we need to go in to develop cost-effective sustainable potato production systems in Maine."—By **Ann Perry,** ARS.

This research is part of Agricultural System Competitiveness and Sustainability (#216) and Plant Diseases (#303), two ARS national programs described at www.nps.ars.usda.gov.

*Bob Larkin is with the USDA-ARS New England Plant, Soil, and Water Research Laboratory, University of Maine, Orono, ME 04469-5753; (207) 581-3367, bob.larkin@ars.usda.gov.**

USDA (D2967-1)

An Improved Method To Estimate Calories



USDA (D2967-2)

Calories in foods are often determined by a system developed at the turn of the 20th century by ARS chemist Wilbur O. Atwater, shown here.

STEPHEN AUSMUS (D2946-3)

ARS physiologist David Baer inserts a study-diet sample into a bomb calorimeter for analysis as biologist Theresa Henderson prepares the next diet sample pellets for testing.

Mom was right. It's important to chew your food fully.

Chewing begins the digestive process of liberating nutrients from their food matrix, and this release is necessary before nutrients are considered "bioaccessible." In addition, the physical form of a food affects its energy and nutrient availability, which is called "bioavailability." Nutrients must be released from a food—becoming bioaccessible—before they are bioavailable to a consumer.

But hard foods, like nuts, for example, may not be fully chewed before they are swallowed. Within the last decade, several published studies have shown that when certain nuts are included in the diet, the amount of fat excreted in stools increases. In theory, this fat was not absorbed because digesting the nuts' cell walls was difficult, and that reduced the bioaccessibility of the fat within the nut.

Researchers at the Agricultural Research Service's Beltsville [Maryland] Human Nutrition Research Center (BHNRC) studied the caloric accessibility and availability of two different tree nuts, pistachios and almonds. They recognized that reduced fat accessibility could affect the available calories provided by a given food matrix. The goal was to study available energy from foods that require significant mechanical and enzymatic action to permit estimates of bioaccessible energy. To achieve that goal, the ARS researchers further developed the commonly used method for estimating the number of calories in the nuts studied.

Updating Traditional Methods

Most often, calories in foods are determined by a system developed by Wilbur O. Atwater at the turn of the 20th century. Atwater was a USDA-ARS chemist at Beltsville and is known as the founder of nutrition as a science in the United States. The system he devised assigns a calorie value to each gram of protein, fat, and carbohydrate found in foods.

Protein and carbohydrates are estimated, on average, to provide 4 calories per gram, and fat is estimated to provide 9 calories per gram. These calorie values are known as the "Atwater Factors." Atwater derived these values by feeding a mixed diet, meaning several foods at once, to a small group of volunteers.

Recently, BHNRC physiologists David Baer and Janet Novotny expanded on the Atwater methods and arrived at a lower estimate than previously reported for the available calories from the two tree nuts

they studied. Their modified method is more accurate for estimating the amount of calories in hard foods. It should work well for other foods, too, the scientists say.

A Look at Pistachios

Baer and Novotny first conducted a feeding study in humans to measure the caloric value of pistachios. In the USDA-ARS National Nutrient Database for Standard Reference, whole pistachio nuts are reported as having 160 calories per 1-ounce serving. The researchers reasoned that if the fat from the nuts is generally less accessible (due to difficulty in digesting the nut's cell wall) than fat from other foods, then nuts may not provide as many calories as previously thought.

The team fed 16 healthy adults pistachios at 3 different levels: none, 1.5 ounces per day, and 3 ounces per day, along with a background, or "base," nut-free diet. Each of the pistachio levels was fed for an 18-day-period. Urine and stool samples were collected and analyzed from all feeding periods.

For the study, Novotny, a mathematician and expert in digestive physiology, wrote a series of algebraic equations. These equations were used to evaluate data gathered from the biological samples, after they had been analyzed using traditional equipment called a "bomb calorimeter." The bomb calorimeter was used to measure calories in the foods that were fed to volunteers (energy in) and also to measure the same foods' excreted remains (energy out). This analysis enabled the team to measure the calories specifically supplied by the target food—pistachios—even though the nuts were consumed along with the base diet.

"A novel feature of our expanded method is the paired-diet approach, where the base diet always consisted of the same foods and composition, thus allowing us to tease out the caloric value of the single target food," says Novotny.

The researchers then compared the metabolizable energy of the nuts fed during each treatment period to the energy estimated by the Atwater Factors. The study suggests that the caloric value of pistachios has likely been overestimated by about 5 percent, because the fat from the nut wasn't completely absorbed by the intestinal tract.

"This fat is likely not absorbed well because the nut's cell walls are hard to break down, whether by chewing or by the action of the microbial enzymes in the gastrointestinal tract," says Novotny. "Because the cell walls are hard to break down, the fat from these nuts is not completely bioaccessible, as required before becoming bioavailable."

The study, which was published in the *British Journal of Nutrition* in 2011, was supported by USDA and Los Angeles-based Paramount Farms, Inc.

Weighing In on Almonds, Too

Baer and Novotny conducted a similar human clinical trial in which they fed the volunteers three different levels of whole almonds as part of a carefully controlled diet for an 18-day period.

According to food labels, almonds provide 168 calories per 1-ounce serving, but the researchers found that the same serving actually provided 129 calories when computed by the modified method. This difference was due in large part to loss of undigested fat, protein, and carbohydrate in the stools, according to the authors.

The study showed that it is possible that the total number of available calories from certain whole nuts, and perhaps other similar foods, may be lower than originally estimated using the traditional specific Atwater Factors. The study, which was published in the *American Journal of Clinical Nutrition* in 2012, was supported by USDA and Almond Board of California.

"These studies point to a reason that a single caloric-value number, or energy density, based on assumed digestibility for all three macronutrients, particularly fats due to their higher number of calories per gram, is not totally appropriate for all foods," says BHNRC director John Milner.—By **Rosalie Marion Bliss,** ARS.

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

David Baer and Janet Novotny are with the USDA-ARS Food Components and Health Laboratory, 10300 Baltimore Ave., Beltsville, MD 20705-2350; (301) 504-8719 [Baer], (301) 504-8263 [Novotny], david.baer@ars.usda.gov, janet.novotny@ars.usda.gov.

Study volunteers consumed nuts as part of a controlled diet to determine the true energy value of the nuts. ARS physiologist Janet Novotny (left) provides 42 grams of pistachios to study participant Susan Conroy as dietetic technician Kenneth Mroz checks the study food on her tray.

STEPHEN AUSMUS (D2952-5)

Addressing Climate Change in Forests, Container Crops

Climate change poses a two-pronged threat to the timber industry in the southeastern United States. Droughts are expected to increase, and tree diseases could become more severe and more common.

Brett Runion and his Agricultural Research Service colleagues Allen Torbert and Steve Prior at the National Soil Dynamics Laboratory in Auburn, Alabama, are helping to address that threat by probing the effects of climate change on diseases that damage trees harvested for paper and wood products. They are also working with university partners to provide guidance to nursery container-crop producers on ways to reduce their climate-change footprint.

Disease, Drought, and Elevated CO_2

Levels of carbon dioxide (CO_2) in the atmosphere are expected to continue increasing. ARS scientists are studying the effects of rising CO_2 levels on various plants and soils.

Loblolly pines are a major resource for the timber industry in the Southeast and are susceptible to a number of fungal diseases. A key question is whether rising CO_2 levels will increase the incidence and severity of disease.

Runion and his colleagues used open-top field chambers to expose loblolly pine and red oak seedlings to twice the normal levels of CO_2 for 6 weeks, then inoculated them with two common fungal pathogens that cause two diseases, pitch canker and fusiform rust. The researchers then placed the seedlings back in the chambers to grow for 7 months.

The diseases were selected because they cause considerable damage to loblolly pine, but the pathogens need different conditions to survive. Fusiform rust needs living tissue, while the fungus that causes pitch canker depends on a toxin to kill plant tissues so that it can feed on the dead material. Red oak was included in the study because it plays a critical role in the fusiform rust reproductive cycle.

Results showed that both loblolly pine and red oak seedlings grown under elevated CO_2 were larger in diameter, height, and weight than seedlings grown under normal CO_2 levels. The researchers expected to see fusiform rust increase under elevated CO_2 levels because the added biomass would give the pathogen more tissue for infection. They also expected reduced levels of pitch canker because the plants would be healthier and better able to defend themselves against the disease.

Instead, they found that for both diseases, severity was the same under elevated CO_2. Disease severity was determined by measuring gall size and length of the lesions formed.

Disease incidence, or the percentage of infected trees, actually decreased. Disease incidence was measured by visually inspecting seedlings for galls or abnormal growths (from fusiform rust) and lesions (from pitch canker).

Trees produce tannins and phenols, which can help fight off infections. Higher CO_2 levels may have increased production of these compounds, Runion says.

The study also showed that higher CO_2 levels alter the timing of the fusiform rust reproductive cycle, which may make pine trees less susceptible. Fusiform rust cycles

A loblolly pine with sporulating cankers on its branches and a small one on the main trunk, caused by the fusiform rust fungal pathogen, *Cronartium quercuum f.sp. fusiforme*.

BRETT RUNION (D2962-1)

BARRY DORMAN (D2980-1)

Trace gas (CO_2, N_2O, and CH_4) sampling in the horticulture dibbling study. Containers with plants are placed into the chambers, and then air is extracted with syringes and assessed for trace gases. Pictured (left to right) are technician Robert Icenogle, doctoral student Chris Marble, plant pathologist Brett Runion, and two student workers.

between oak and pine trees via spore dispersal. Pine tissues don't stay highly susceptible to the spores for long, and the researchers found that elevated CO_2 lengthened the interval between inoculation and spore formation in the red oak seedlings.

"It is possible that the delay in spore formation on the oaks could result in lower infection levels in pines, if the delay causes spores to be dispersed after the pine tissues have begun to harden and become less succulent," Runion says. Results were detailed in the journal *New Forests* (2010).

Climate change is also expected to increase the number and severity of droughts, which can cause trees to wilt, drop leaves, and perhaps even die. Trees usually recover from a drought once it passes, but a tree infected with pitch canker can exhibit the same symptoms, and it won't recover when the drought ends.

A shoot of a loblolly pine naturally infected by the pitch canker fungal pathogen, *Fusarium circinatum*.

BRETT RUNION (D2963-1)

Foresters assumed such dieback in 800 acres of southeastern loblolly pines several years ago was caused by drought stress, but when the drought ended, they learned that the symptoms were caused by pitch canker exacerbated by the drought, Runion says. In a separate study, he is trying to determine whether droughts increase the severity of pitch canker.

Greenhouse Gas Guidance for Nursery Operators

Christopher Marble and Charles Gilliam, researchers at Auburn University, joined with Runion, Prior, and Torbert to study the effects of container sizes and fertilizer-application methods on greenhouse gas emissions from container crops. There are three methods typically used to apply fertilizer to container crops: incorporating it into the potting media, top dressing the soil, and "dibbling"—where a small hole is poked in the soil, the fertilizer is placed into it, and the crop is planted over the fertilizer.

The researchers used each method to fertilize azaleas grown in containers. They measured levels of CO_2, nitrous oxide (N_2O), and methane in enclosed chambers weekly throughout the 6-month growing season. Plants were harvested, ground up, and weighed so that the amount of carbon sequestered in them could be approximated.

Results showed negligible differences among the three fertilizer treatments in root and shoot weights, amount of carbon stored in the plants, and methane levels.

Dibbling released the lowest levels of CO_2 and N_2O. Incorporating fertilizer, which is a common practice in the horticulture industry, caused slightly higher CO_2 levels and three times more N_2O emissions than the other two treatments.

"It may take a while for producers to change their practices, but our role is to give them the information they need so they can make informed decisions and adapt to possible emission regulations in the future," Marble says. The results were published in *HortScience* (2012).

In another study, the researchers compared greenhouse gas emissions from four different sizes of containers used to grow dwarf yaupon holly, a popular woody shrub. They compared 1-year emissions from 3-liter (trade gallon), 1-gallon, 2-gallon, and 3-gallon containers.

Results, detailed in the *Journal of Environmental Horticulture* (2012), showed that CO_2 and N_2O emissions generally increased proportionately as container sizes increased, while methane levels were minimal for all container sizes. The researchers noted that container size is just one factor growers need to consider. Smaller containers are placed closer together than large containers, resulting in almost four times more plants per acre, which in turn would release higher levels of CO_2 and N_2O. The researchers also noted that regardless of container size, production of most nursery crops would likely result in a net carbon gain, even while in production, because of carbon being stored in growing biomass.

The study was the first to compare container-crop emissions based on container size, and Marble says the results have proved useful for estimating state and regional emissions from nursery operations.—By **Dennis O'Brien,** ARS.

This research is part of Climate Change, Soils, and Emissions, an ARS national program (#212) 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.

Experimental Wildfire-Retardant Coating May Help Protect Homes

At the Western Regional Research Center in Albany, California, food technologist Artur Klamczynski (left) and plant physiologist Greg Glenn prepare to use an infrared heater, located behind them, to conduct burn tests of siding coated with experimental fire-retardant gel.

When a forest or brushland wildfire threatens to engulf nearby neighborhoods, some homeowners might opt to quickly spray the entire exterior of their house with a temporary fire-retardant coating. Now, a team of Agricultural Research Service scientists in California—one of America's most wildfire-prone states—has shown that an experimental fire-retardant gel made of sodium bentonite clay, cornstarch, and water may offer better, more affordable protection than gels made from other compounds.

Preliminary research, led by plant physiologist Greg Glenn at the agency's Western Regional Research Center in Albany, provides a foundation for more extensive tests of the promising, all-natural coating.

According to Glenn, results suggest that a layer of gel—about one-quarter-inch thick—"may protect wood-based home siding for up to 30 minutes."

Depending on the circumstances, that might be long enough to save a home. "In a best-case scenario," he says, "all you might have to do is wash the coating off your house after the fire."

For the research, Glenn and coinvestigators cut planks of residential wood-based siding into 7-inch squares, about 3/8-inch thick, then coated all but the "control" squares with the experimental gel, a commercial gel, or other formulations.

The experimental clay-and-starch gel outperformed the other coatings in several experiments.

For example, "drying tests" showed that the gel kept its moisture longer—a quality important for a fire retardant. In those tests, the coated siding was kept for 6 hours in an oven set at 111˚F, to simulate the moisture-robbing effects of the high temperatures and hot, drying winds typical of "high-fire-danger" weather in some parts of the country. The 6-hour timeframe was chosen as one example of how many hours in advance of a wildfire a protective coating might be applied.

In "burn tests," siding coated with the clay-and-starch gel took longer to reach 392°F, the temperature at which wood-based siding may begin to burn and char. In these experiments, the coated siding was exposed to 960°F heat—a temperature not uncommon for a brushfire, for example—until the siding reached the 392°F burning point.

Other tests, in which the squares were positioned upright, showed that the gel was less prone to sliding, technically known as "slumping," toward the bottom of the squares. The starch, Glenn says, helped the coating to stay in place and, in so doing, shield the siding.

Sodium bentonite clay and starch are not new to firefighting, but the California team's idea of combining these materials to form a fire-retardant coating is apparently a first, as is the team's detailed analysis of the coating's effectiveness. ARS is seeking a patent for the research.

Chemist Bor-Sen Chiou, food technologist Artur Klamczynski, and agricultural engineer Zhongli Pan, all at Albany, and former Albany researcher Gokhan Bingol collaborated with Glenn in the study. They documented their findings in a peer-reviewed article published in 2012 in *Fire Safety Journal*.—By **Marcia Wood,** ARS.

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

Gregory M. Glenn is with the USDA-ARS Western Regional Research Center, 800 Buchanan St., Albany, CA 94710; (510) 559-5677, greg.glenn@ars.usda.gov.

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

Locations Featured in This Magazine Issue

Locations listed west to east.

Map courtesy of Tom Patterson, U.S. National Park Service

Albany, California
9 research units ■ 241 employees

Pullman, Washington
6 research units ■ 136 employees

Tucson, Arizona
2 research units ■ 54 employees

Las Cruces, New Mexico
2 research units ■ 49 employees

High Plains Grasslands Research Station, Cheyenne, Wyoming
1 research unit ■ 27 employees

Fort Collins, Colorado
7 research units ■ 141 employees

North Great Plains Research Laboratory, Mandan, North Dakota
1 research unit ■ 47 employees

Grazinglands Research Laboratory, El Reno, Oklahoma
2 research units ■ 43 employees

Ames, Iowa
8 research units ■ 462 employees

Columbia, Missouri
3 research units ■ 86 employees

Urbana, Illinois
2 research units ■ 37 employees

Auburn, Alabama
2 research units ■ 46 employees

Tifton, Georgia
3 research units ■ 103 employees

University Park, Pennsylvania
1 research unit ■ 42 employees

Robert W. Holley Center for Agriculture and Health, Ithaca, New York
3 research units ■ 62 employees

Fort Detrick, Maryland
1 research unit ■ 46 employees

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

New England Plant, Soil and Water Research Laboratory, Orono, Maine
1 research unit ■ 10 employees

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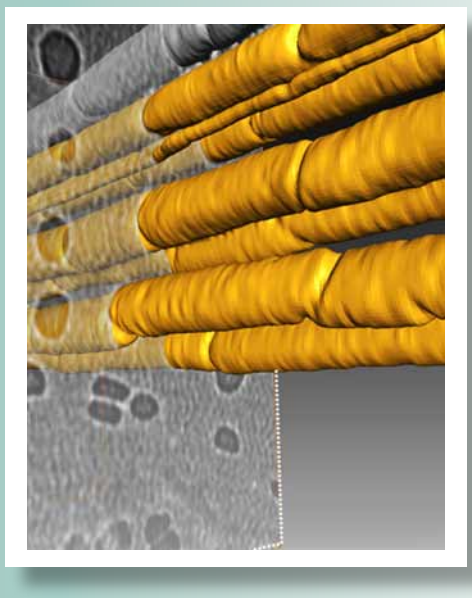
Spotlight On ...



A Plant's Vascular Network

An ARS plant physiologist has developed a way to create three-dimensional views of xylem tubes—vessels that deliver water and nutrients from the roots to the leaves in plants—using micro CAT scan technology.

Image courtesy of Andrew McElrone, ARS, and Craig Broderson, University of Florida.