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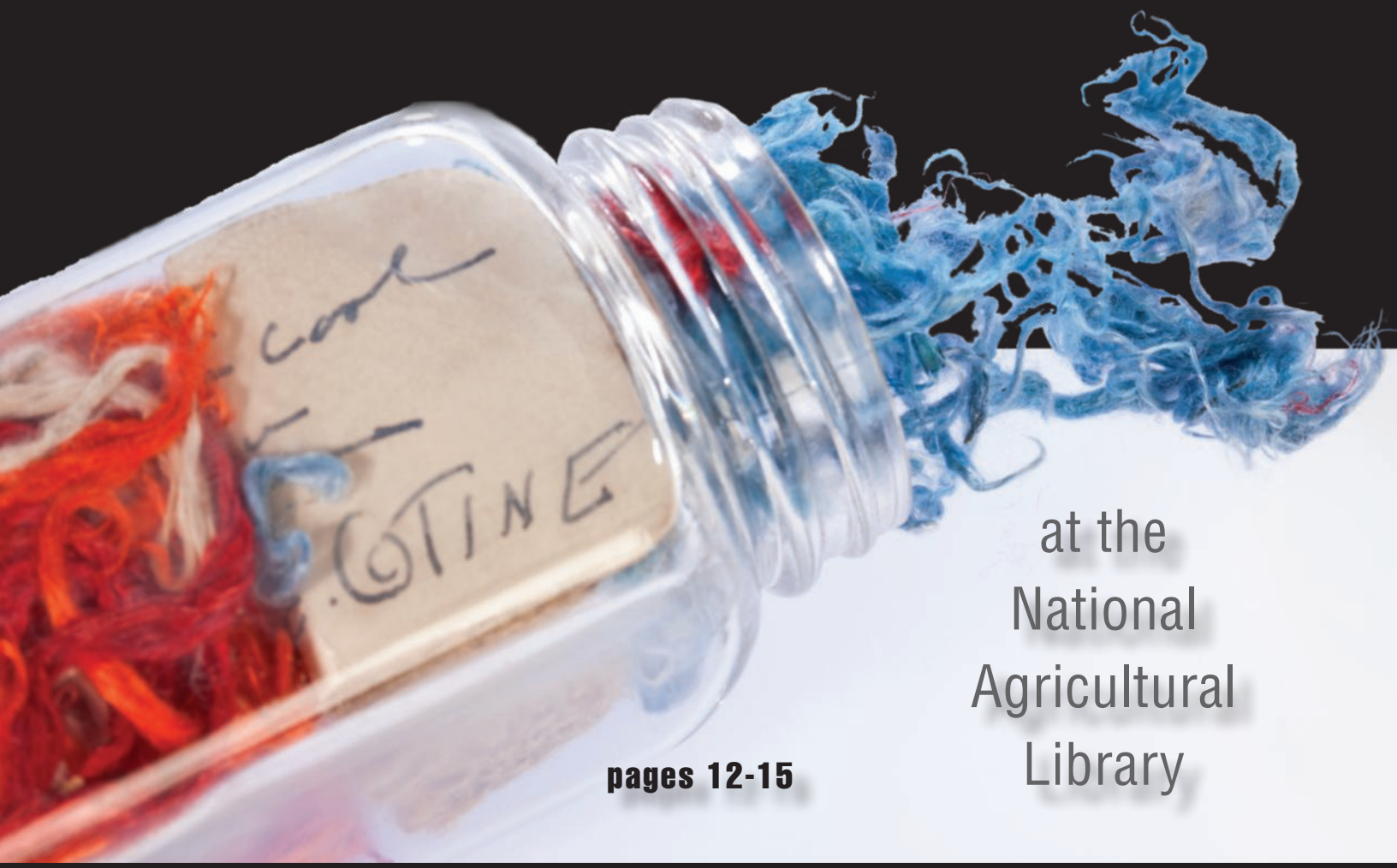
Agricultural Research

Preserving Threads of History



at the National Agricultural Library

pages 12-15

FORUM

ARS Scientists: All-Purpose Agronomists

From the flowerpot to the crop field, Agricultural Research Service scientists tackle issues that pay off in a homeowner's pride, a golfer's putt, a farmer's profits—and the nation's environmental protection.

For instance, one of the biggest issues facing farmers today is deciding how to manage their crop fields: till or no-till? The costs of transitioning from conventional to no-till farming can be considerable, so farmers are not always eager to make the switch.

Soil scientist David Huggins, who works at the ARS Land Management and Water Conservation Research Unit in Pullman, Washington, is looking for data that will give producers another reason to consider using no-till in Washington's rolling fields of winter wheat. In this region, known as "the Palouse," every slope and aspect can affect crop performance and crop yield—and managing dryland production is made even more challenging by the way the complex landscape and variations in soil affect the soil's water-storage capacities.

One morning, as Huggins watched a blizzard blowing outside his window, he decided to investigate how snow retention differed on no-till fields and conventional fields and how the differences affected the storage of soil water. For 2 years, he manually measured snow depth and density and soil water storage at hundreds of points across a no-till crop field and a conventional-till crop field.

Huggins found that standing wheat residue on the no-till field significantly increased the amount and uniformity of snow cover across the entire field, a pattern that resulted in a more uniform distribution of soil water and that increased soil water recharge rates. By his calculations, this could add up to increased profits from winter wheat by an average of $30 per acre and as much as $54 per ridge-top acre—findings that underscore the current advantages of no-till management. You can read more about this study, summarized on page 8.

What about the advantages of no-till for farmers in the future? At the ARS Agricultural Systems Research Unit in Fort Collins, Colorado, research leader Laj Ahuja conducted several modeling studies that simulated the effects of climate change projections on three crop rotation systems—wheat-fallow, wheat-corn-fallow, and wheat-corn-millet—to see how yields might be affected by future climate shifts. In one study, his simulations projected higher wheat yields resulting from no-till management, because evaporation rates were lower in fields protected by crop residues, which led to higher levels of soil water retention. His modeling indicated that as air temperatures and atmospheric CO_2 concentrations increase, wheat yields from no-till wheat-fallow rotations are expected to exceed yields produced with conventional tillage through the year 2075. This story begins on page 6.

ARS research also extends to turfgrass and ornamental crops—always with an eye on protecting the environment. For example, as golf courses strive to become even "greener," a major concern is that pesticides and nutrients used to maintain play-worthy turf can be carried into nearby waterways via runoff. A story in an upcoming magazine issue will feature ARS work showing how the type of core cultivation affects pesticide transport and nutrient concentrations in runoff from the turf.

Ornamental crops need care and feeding just like turfgrass and field crops do, and their fertilizers contain compounds to help the flowers take up needed micronutrients. But these compounds, called "chelating agents," don't break down easily in the soil and may be one source of iron and other heavy metals found in nearby surface waterways.

Horticulturalist Joseph Albano, who works at the U.S. Horticultural Research Laboratory in Fort Pierce, Florida, has found a promising alternative to these chelating agents. In several greenhouse studies, Albano used EDDS—a readily biodegradable chelating agent—and observed that there was no significant difference in the health, growth patterns, or micronutrient levels in marigolds grown with EDDS and marigolds grown with other popular iron chelating agents. Since EDDS is biodegradable, it will not persist in the environment and is less likely to take up heavy metals in soils and transport them waterways. The story on page 22 has more details on this research.

A planter filled with marigolds. A turfgrass fairway that accommodates an endless parade of golfers. A field of wheat covering the rolling hills of the Palouse or flourishing on Colorado's high plains.

ARS has a hand in all of them.

Steven R. Shafer
ARS Deputy Administrator
Natural Resources and Sustainable Agricultural Systems
Beltsville, Maryland

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

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Tom Vilsack, Secretary
U.S. Department of Agriculture

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

Edward B. Knipling, Administrator
Agricultural Research Service

Sandy Miller Hays, Director
Information Staff

Editor: **Robert Sowers** (301) 504-1651
Associate Editor: **Sue Kendall** (301) 504-1623
Art Director: **BA Allen** (301) 504-1669
Photo Editor: **Tara Weaver-Missick** (301) 504-1663
Staff Photographers:
Peggy Greb (301) 504-1620
Stephen Ausmus (301) 504-1607

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(D2576-2)

The stately building that once housed the U.S. Department of Agriculture in Washington, D.C., circa 1890. This photo is preserved at the National Agricultural Library, along with countless other historical items. Story begins on page 12.

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23 Locations Featured in This Magazine Issue

Cover: This colorful fiber is one of the specimens in the USDA Fiber Collection, part of the many special collections documenting USDA's efforts leading up to the Department's 150th anniversary in 2012. The collections include correspondence, raw research notes, images, and artifacts and provide a record of how USDA has carried out its mission in its first 150 years. Story begins on page 12. Photo by Peggy Greb. (D2553-1)

Climate Change May Help Restore Arid Grasslands

Agricultural Research Service ecologist Debra Peters works in a daunting environment—an expanse of Chihuahuan desert in New Mexico that was once known as the "journey of the dead." This is also where the U.S. Department of Agriculture established the Jornada Experimental Range, a 200,000-acre tract outside Las Cruces where scientists conduct research to help maintain sustainable livestock production and conserve natural resources on the surrounding arid land.

"We're always looking for ways to relate grass production to precipitation, because this helps us extrapolate grass production to forage production," says Peters. It's a data-driven quest, and as a research facility celebrating its centennial in 2012, the Jornada is rich in data.

Peters was recently able to leverage some of that information to explore an intriguing hypothesis: In the future, warmer air temperatures from global climate change might generate more rainfall in the typically dry climate. If so, this could push the shrub-dominated desert rangeland over what Peters calls the "threshold of change" back into an ecosystem that supports growth and establishment of grasses.

Several years ago, Jornada researchers noticed grasses were starting to become established on land that had been vegetated with mesquite and creosote bushes. "We had some wet years that started in 2004 and continued through 2008," Peters says. "There had been individual wet years before, but this was the first time there were five in a row. We thought the unusual grass production could be a response to the cumulative effect of the precipitation."

ARS ecologist Debra Peters (left) and New Mexico State University ecologist Jin Yao evaluate vegetation before estimating plant production at the Jornada Experimental Range.

STACEY PETERS (D2568-1)

JOHN ANDERSON (D2566-1)

In 2003, at the end of a long drought, mesquite and bare soil dominate a study site at the Jornada Experimental Range.

Mapping the Changes

Small-scale grazing started on the Jornada in the 1600s, and maps compiled in 1858 by amateur cartographers on horseback indicated that more than 80 percent of the surveyed area was covered by grasslands. But by 1998, grasslands covered only about 15 percent of the same area. The same map collections showed mesquite coverage growing from 15 percent in 1858 to 59 percent in 1998, while tarbush and creosote shrubs had spread across some 20 percent of the previous grassland.

Peters and several other researchers at the Jornada station used these maps to compare changes in plant distribution with precipitation and to identify long-term trends in desertification. After the team pinpointed the changes in vegetation distribution over the past 150 years, they accessed data collected since 1989 by collaborators from the Jornada Basin Long Term Ecological Research project funded by the National Science Foundation. Data was available from five desert ecosystem types: upland grasses; playa grasslands; and mesquite, creosotebush, and tarbush shrublands. Then they compared the changes in herbaceous and woody species in average-rainfall years from 1989 to 1999 with changes after a sequence of dry years from 2000 to 2003 and after a series of wet years from 2004 to 2008.

The changes were identified by measuring biomass, aboveground net primary production (ANPP), plant diversity, and rain-use efficiency, which refers to grams of plant production per unit of precipitation. Ecologists use rain-use efficiency as a key indicator that signals ecosystem function change and potential grass recovery.

During the wet years, all study plots showed an increase in plant production, mainly by herbaceous plants. This increase was the highest on upland grasslands and mesquite shrublands, which were the sandiest sites.

When the scientists conducted additional comparisons, they found ANPP and plant diversity in three ecosystem types—upland grasses, mesquites, and tarbushes—were significantly higher in the wet period than the dry period. But it wasn't just a linear relationship, since plant production in upland grasslands and mesquite shrubland during the wet period was greater than expected based on production measured during the dry period. Peters thinks that the wet years prompted a change in the interactions between grass plants and soil water, which in turn started a positive environmental feedback loop that supported additional growth and establishment of grasses.

JOHN ANDERSON (D2567-1)

By 2008, after 5 consecutive wet years, perennial grasses were growing in the previously bare spaces between and around the shrubs.

Back to Grass

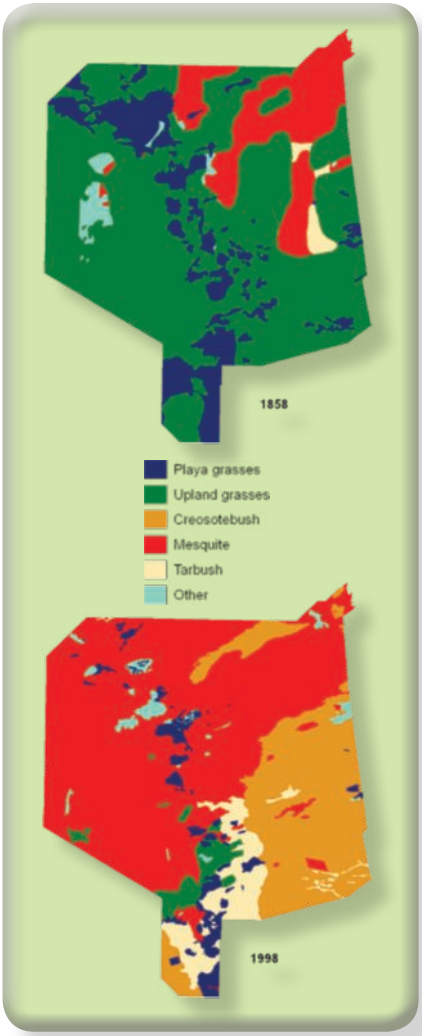
"Grass can germinate even during dry years, but it needs several years of moisture before it becomes established and puts out seed. And once grass is established, organic material collects at its base, so there's an increase in biomass and litter on the soil surface," Peters says. "When it rains hard on the Jornada, the water runs across the soil surface as sheet flow, but the accumulating biomass dams the flow. All of this makes conditions even better for grass growth, because there's an increase in the level of soil moisture and the organic matter that supports plant growth, which allows survival even when conditions become dry again. In addition, the established grass survives long enough to put out seed to continue the cycle."

Peters believes that if future climate results in more regional wet-year intervals, this could support the conversion of desertified shrub lands to savannas that support a mix of shrubs and grasses—and maybe the return to an ecosystem dominated by grasses. This back-and-forth dominance between grasses and shrubs has occurred several times in the Southwest over the past 10,000 years.

"Land managers have tried a number of things over the last 80 years to reestablish grass, but very little has worked," Peters says. But she thinks that with sufficient increased precipitation over a sequence of years—and carefully managed grazing—the spread of productive grasslands could keep desert woody plants in check.—By **Ann Perry,** ARS.

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

Debra Peters is with the USDA-ARS Jornada Experimental Range and the Jornada Basin Long Term Ecological Research Program, 2995 Knox St., Las Cruces, NM 88003; (575) 646-4842, deb.peters@ars.usda.gov.



COURTESY USDA-ARS JORNADA EXPERIMENTAL RANGE (D2591-1)

Maps of the Jornada Experimental Range show that grasses covered more than 80 percent of the land in 1858 (top) but covered only about 15 percent by 1998 (bottom). Mesquite, creosotebush, and tarbush displaced the grasses.

EcoTrends ARS ecologist Debra Peters headed up the development of the EcoTrends Project, a multiagency effort to collect and synthesize long-term data for examining trends in Earth's ecosystems.

"It started in 2006 as a result of a National Science Foundation meeting where we tried to compare trends in long-term data across different systems, but the data wasn't in a format we could work with," Peters says. "So we wanted to create something easier to use." Peters and her colleagues created more than 60 standard data sets derived from detailed meteorological and biotic measurements that had been taken at 50 different sites. Much of the work involved converting data from individual locations into a format that was consistent and accurate across all locations—a task that took 4 years. The data will be available in a book to be published by the U.S. Department of Agriculture and at www.ecotrends.info. Peters and her colleagues hope that EcoTrends will encourage scientists, students, teachers, and decisionmakers to use long-term data to learn more about shifts in global climate change and how those shifts could affect local, regional, and large-scale ecosystems.

TIM GREEN (D2564-1)

HOTTER SUMMERS

Could Trump CO_2 Benefits on Dry Cropland

Reducing tillage is one major hope for salvaging some of the crop yield losses predicted for the semi-arid Central Great Plains due to climate change—as well as for conserving water as supplies decline.

That's one finding from an innovative Agricultural Research Service study that combined a computer model with 15 to 17 years of field crop and climate data—and Colorado Water Conservation Board global change projections for Colorado through the year 2050. The board made a synthesis summary of climate change for Colorado from projections of 16 different global climate change models for three greenhouse gas emission scenarios, reported by the United Nations Intergovernmental Panel on Climate Change in 2007, and other climate change reports for Colorado.

The multi-model average projections call for an increase in equivalent carbon dioxide (CO_2) levels from 380 parts per million (ppm) in 2005 to 550 ppm by 2050. They also call for Colorado's summer temperatures to rise by about 5˚F by 2050. The scientists in the ARS study extrapolated the projections to the year 2100 by assuming a linear increase of CO_2 and temperature.

The Colorado climate projections through 2050 came from a report commissioned by the board and carried out by the University of Colorado-National Oceanic and Atmospheric Administration Western Water Assessment.

Rare Look at Global Warming Effects on Crop Rotations

Research leader Laj Ahuja and colleagues at the ARS Agricultural Systems Research Unit at Fort Collins, Colorado, used the Root Zone Water Quality Model, version 2 (RZWQM2), for their computer model runs. They superimposed the multi-model average climate projections onto data from 15 to 17 years of experiments with three crop rotation systems—wheat-fallow, wheat-corn-fallow, and wheat-corn-millet—to see how yields might be affected in the future.

They simulated different combinations of three climate change projections: rising CO_2 levels, rising temperatures, and a shift in precipitation from late spring and summer to fall and winter. They ran the model for each of the 15 to 17 years of available crop data for each cropping system.

All Yields Down

They found that when all three factors were combined in a model run, yields of all crops went down in all three cropping systems, progressively to the year 2100. The decline in corn and millet yields was more significant than that in wheat yields. Ahuja says the data suggests that the temperature increase would decrease growth of plants while increasing their potential demand for water.

Left: This dome is a weather facility at Greeley, Colorado, one of many stations that gather multiple years of climate data used in combination with a model to project future crop yields in response to various climate changes.

"The negative effects of warmer temperatures would outweigh the benefits of higher atmospheric CO_2 on all the crops in the rotations. High levels of CO_2 enhance photosynthesis in crops like wheat and help plants retain water by causing the stomatal pores on their leaves to partially close," Ahuja says.

Ahuja did the study with colleagues at Fort Collins, including Jonghan Ko—an agronomist/computer modeler who is now at Chonnam National University in Gwangju, South Korea—and David Nielsen, an ARS agronomist at Akron, Colorado.

The crop data came from field crop experiments that are ongoing at the ARS Central Great Plains Research Station in Akron, involving rotations of wheat and other crops.

Ahuja also simulated yields of the three crop rotations over the past 96 years of climate data, looking only at CO_2 effects, from 300 ppm in 1912 to the current level of 380 ppm. That data, too, came from the Akron station, which was established by the U.S. Department of Agriculture in 1907.

"This study allowed us to doublecheck the effects of high CO_2 over nearly a century of climate data, with actual rather than projected fluctuations in precipitation and weather," Ahuja says.

They found that the higher CO_2 increased yields of wheat and millet, but not corn.

Models and Long-Term Data Best for Predicting Climate Change Effects

"Calibrating computer models like RZWQM2 with long-term field and climate data provides the best way to predict the effects of climate change and the farming strategies that will make the best use of limited water," Ahuja says. "Climate change will only make water scarcity worse for farm crops like wheat, corn, or millet in areas like the semi-arid Central Great Plains.

"Although the results of this study only apply to nonirrigated crops in the central Great Plains, the technique could be used elsewhere in the country with different crops, with or without irrigation."

Ahuja and colleagues used a hybrid version of RZWQM2, adjusted to the better data acquired in wheat FACE (Free Air Carbon Enrichment) and T-FACE (Temperature Free-Air Controlled Enhancement) experiments at the ARS Arid-Land Agricultural Research Center in Maricopa, Arizona. This data gives a more accurate accounting of the enhanced photosynthetic growth effects from higher CO_2 levels. It also adjusts for the water-saving effects of higher CO_2 levels.

Ahuja and colleagues released the original Root Zone Model in 1992 and, in 2007, released an improved version that links to better crop-growth models.

No-Till Helps—To a Point

Ahuja simulated changing planting dates up to a month earlier and using no-till to see whether either option would ameliorate yield losses, but only the no-till option helped. No-till leaves crop residue on the field after harvest, forming a protective layer that reduces evaporation and helps the soil retain water.

"In the wheat-fallow rotation with no tillage, wheat yields were higher than with conventional tillage through 2075," he says. "This shows that crop rotation and tillage practices have a greater effect on yields than any 'advantages' that might be offered by climate change, such as growth-boosting and water-saving effects from CO_2. When summer temperatures reached 8°F warmer in 2100, even the no-till yield advantage was lost.

"This is a unique study of the effects of climate change on three crop rotations. As far as I know, this is the first study of climate change effects on millet," Ahuja says.

New Crop Varieties Answer in Long Run

"There is always room for improvement," Ahuja says. "For example, the computer models currently don't account for new crop varieties that are better adapted to climate change or for crops' possible natural adaptations—within each variety—to conditions over time. We could improve accuracy by using more complete and detailed models of crop photosynthesis and transpiration. And we have to develop better ways to downscale global climate change prediction data to fit specific regions, especially for a state like Colorado whose climate is made highly variable by the varying elevations of the Rocky Mountains. For now, no-till provides one answer for some crops. For the long run, breeders and geneticists will have to develop varieties that can tolerate higher temperatures or change to crops that are both high-temperature and drought tolerant, such as replacing corn with sorghum."—By **Don Comis,** formerly with ARS.

This research is part of Water Availability and Watershed Management (#211) and Agricultural System Competitiveness and Sustainability (#216), two ARS national programs described at www.nps.ars.usda.gov.

Laj Ahuja is in the USDA-ARS Agricultural Systems Research Unit, 2150 Centre Ave., Bldg. D, Suite 200, Fort Collins, CO 80526; (970) 492-7315, laj.ahuja@ars.usda.gov.

The data from this FACE (Free Air CO_2 Enrichment) experiment was used to validate the model for CO_2 effects on plant growth.

BRUCE KIMBALL (D2563-1)

No-Till and Snow Can Help Crops Grow

"Water availability is a major limiting factor of dryland crop productivity in the Palouse," says Agricultural Research Service soil scientist David Huggins. "We receive 70 percent of our yearly precipitation in the winter, and we need to store as much of that water as possible in the soil so it can be used in the summer by crops."

Which is why Huggins sent two technicians out in a January snowstorm to measure how much snow had fallen on two nearby crop fields. It was the beginning of a field-scale study that compared how no-till and conventional-till management affect snow accumulation, snow distribution, and the spatial variation of soil water.

"One of the benefits of no-till is that crop residues left standing on the soil surface can insulate soil from water evaporation and trap snow to provide more stored water," explains Huggins, who works at the ARS Land Management and Water Conservation Research Unit in Pullman, Washington. "But until now, we hadn't measured how crop residues could affect snow accumulation and soil water levels across an entire field."

The study was conducted near Pullman, at the Washington State University Cook Agronomy Farm (CAF) and a neighboring private farm, both of which have the hilly topography characteristic of the region known as "the Palouse." Some of the CAF has been under continuous no-till management since 1999. For 2 years, snow depths, density, and soil water storage were measured manually at hundreds of points across the fields on both farms. Residue height at data-collection points was also measured on the no-till fields.

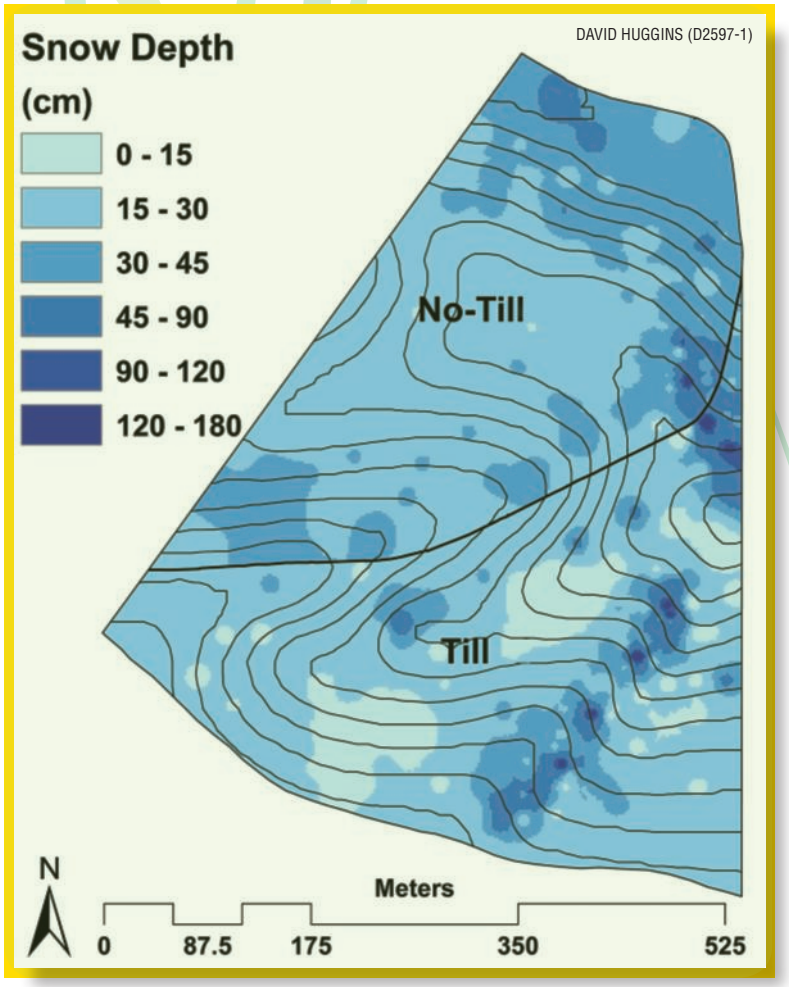
The researchers found that standing wheat residue on the no-till farm significantly increased the amount and uniformity of snow cover across the entire field. Snow depths on the no-till field ranged from 4 to 39 inches with an average depth of 11 inches, while snow depths on the conventional-till field ranged from 0 to 56 inches with an average depth of 8.5 inches.

This pattern made soil water distribution more uniform and increased soil water recharge rates on the no-till farm. The more uniform snow distribution under no-till was particularly apparent for ridge tops and steep south-facing slopes where there was typically 4 to 8 inches more snow than on conventionally tilled fields.

"On conventionally tilled fields, snow just blows off ridge tops. Then it accumulates as large drifts on north slopes and bottom lands, where it can cover winter wheat crops that have emerged," Huggins says. "The higher snow cover on conventional-till north slopes can really slow down crop growth and development. In addition, farmers have to work around more wet or snow patches in the spring—and when the snow drifts melt, soil erosion is promoted."

Huggins calculated that the greater storage of soil water in no-till systems could increase winter wheat yield potential by 13 bushels per acre on ridge tops, 6 bushels per acre on south-facing slopes, and 3 bushels per acre in valleys. As a result, regional farmers could increase their winter wheat profits by an average of $30 per acre and as much as $54 per ridge-top acre.

"We want to encourage Pacific Northwest farmers to switch to no-till," Huggins says. "This study helps us do that, because we can use the results to show how no-till positively influences soil water storage and yield potential across a field—and it also links this information to field-scale precision management of soil fertility."—By **Ann Perry,** ARS.



Snow depth after a January snowstorm on a field of no-till wheat (with standing crop residue) and conventionally tilled wheat (no residue). The residue in the no-till crop promoted a more even snow distribution and less drifting.

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

David Huggins is in the USDA-ARS Land Management and Water Conservation Research Unit, Johnson Hall, Washington State University, Pullman, WA 99164; (509) 335-3379, david.huggins@ars.usda.gov.

New Blueberry Varieties Being Readied for Sale

Blueberry growers and consumers alike stand to benefit from Gupton and Pearl, two new southern highbush cultivars developed by Agricultural Research Service researchers in Poplarville, Mississippi. In addition to high yields of plump, flavorful berries and vigorous growth, the new cultivars should give southern growers a jump on the lucrative early-ripening fresh market, which starts in April and May.

"There's been limited acreage of southern highbush blueberries because their lack of vigor has made them difficult to grow. However, we've overcome that problem to a large extent by developing hybrids from crosses made among southern highbush germplasm showing greater adaptation to the southeastern United States," says Stephen Stringer, a geneticist at ARS's Thad Cochran Southern Horticulture Laboratory in Poplarville.

Gupton and Pearl, released in 2006 and 2010, respectively, are finding their way into crop fields and nurseries as more propagative material becomes available from tissue-culture operations and softwood cuttings.

"Several nurseries have requested Pearl, and there are some growers in Mississippi who have Gupton in small plots in their fields. Gupton's also being evaluated in some trials in North Carolina and other southern states and is looking very good," reports Stringer. He collaborated on the cultivars' development and testing with ARS horticulturists Donna Marshall and James Spiers (retired) and ARS small-fruits breeder Arlen Draper (retired).

Southern production of blueberries, both for fresh and frozen (processing) markets, is situated in the Gulf Coast states of Mississippi, Florida, Alabama, and Texas, and the Carolinas and Georgia. In 2002, for the first time, consumer demand for fresh blueberries overtook that of frozen blueberries nationwide and has since retained its lead, with Americans consuming 1.1 pounds per person in 2010 versus 0.6 pounds for frozen berries.

STEPHEN STRINGER (D2583-1)

Prince, an early-ripening rabbiteye blueberry released by ARS.

Michigan, Maine, New Jersey, and other northern states lead U.S. cultivated blueberry production, valued at nearly $590 million, but year-round demand for the antioxidant-rich fruit has given southern growers a chance to enter the fray, especially the early-ripening fresh market. Gupton and Pearl are the latest southern highbush blueberries to emerge from the Poplarville program with that market squarely in mind, says Stringer. Prior to release, both cultivars underwent several years of field evaluation in south-central Mississippi for vigor, yield, berry quality, splitting resistance, and other traits.

In trials, Gupton and Pearl flowered in mid to late March and were ready for harvest about 21 days before the earliest ripening rabbiteye cultivars, which have been the predominant type grown in the South. Gupton and Pearl produce medium to large, flavorful berries with light-blue color and a high soluble-solids content. The cultivars grow as sturdy, upright shrubs and have a chilling requirement (necessary for springtime blooms) of 400 to 500 hours at temperatures below 45°F.

In addition to the highbush releases, the Poplarville team is readying specialty cultivars for various niche markets, including U-pick farms and bakers, and cultivars with jumbo-sized berries weighing nearly 5 grams.

"We also released Prince, an early-ripening rabbiteye that can be harvested 7-10 days sooner than existing rabbiteyes," adds Stringer.—By **Jan Suszkiw,** ARS.

REGGIE DAVIS (D2582-1)

Geneticist Stephen Stringer examines a rabbiteye blueberry (selection MS1262) that will soon be released. He and collaborators have developed new varieties of southern highbush and early-ripening rabbiteye blueberries.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301) and Crop Production (#305), two ARS national programs described at www.nps.ars.usda.gov.

Stephen Stringer and Donna Marshall are with the USDA-ARS Southern Horticulture Research Laboratory, 810 Hwy. 26 West, Poplarville, MS 39470; (601) 403-8768 [Stringer], (601) 403-8762 [Marshall], stephen.stringer@ars.usda.gov, donna.marshall@ars.usda.gov.

Cranberries! Native Fruit's

Maybe you remember when cranberries mostly showed up at year-end holidays as the perfect relish for your roast turkey.

In the 1960s, however, the introduction of flavorful cranberry juice beverages helped build a new, year-round use for the berry. These pleasant blends balanced the cranberry's naturally tart flavor with the sweetness of other favorite fruits such as apples and pears.

In the 1990s, the launch of dried, sweetened cranberries, which look somewhat like little red raisins, brought new attention to the colorful fruit.

Cranberries are rich in fiber, low in sodium, and provide vitamin C and potassium. They also contain intriguing natural compounds referred to as flavonoids, polyphenols, or, more generally, phytochemicals.

Phytochemicals are of ongoing interest to nutrition and medical researchers worldwide. For instance, cranberry phytochemicals have been the focus of a series of studies by chemist Ronald L. Prior and colleagues. Formerly with the Agricultural Research Service at the Arkansas Children's Nutrition Center in Little Rock, Prior is now an adjunct professor of food science at the University of Arkansas in Fayetteville.

Cranberry Juice-Processing Leftovers: A Treasure Trove of Phytochemicals?

In one investigation, Prior collaborated with Brittany L. White, formerly at the university and now a food technologist with ARS at Raleigh, North Carolina, and with Luke R. Howard, a professor in the university's food science department, to closely examine the kinds and amounts of phytochemicals in cranberry pomace—the stems, skin, and pulp that are left when the plump berries are pressed to make juice or canned products.

"Cranberry processors are looking for new, value-added uses of these byproducts," says Prior. Knowing more about the polyphenols in pomace might lead to new ways to build new markets for it.

Much is already known about the major polyphenols in fresh cranberries. But the Arkansas study is apparently one of the first to extensively investigate and document the kinds and amounts of major cranberry-pomace polyphenols.

The researchers used several sophisticated analytical procedures, including high-performance liquid chromatography-electrospray ionization-mass spectrometry and matrix-assisted laser desorption time-of-flight mass spectrometry. These procedures can measure the molecular weight of pomace constituents and, from that, determine their identity. If appropriate reference standards are available, the quantity of each constituent can be determined.

Among other findings, the scientists determined that the pomace contained "appreciable levels" of flavonols, a class of polyphenols that includes, for example, quercetin and myricetin.

Fresh whole cranberries are already known to contain high levels of flavonols—more than most other berries and, in fact, more than most fruits or vegetables. But the research was the first to show that nearly half of the total flavonol content of whole berries was left behind in the pomace instead of making its way into juice.

Published in the peer-reviewed *Journal of Agricultural and Food Chemistry,* the study is the most up-to-date analysis of its kind for cranberry pomace.

The findings are a useful, readily accessible reference for medical and nutrition researchers, food processors, and others.

Tactic Targets "Unextractable" Pomace Components

A related investigation showed that the conventional procedure for gleaning polyphenols from pomace doesn't fully extract proanthocyanidins, or PACs, an important class of polyphenols.

The normal extraction process relies on a solution of acetone, acetic acid, and water. The team of White, Howard, and Prior examined an alternative approach—one that requires exposing pomace to various concentrations of sodium hydroxide at 140˚F for 15 minutes. This method re-

Garnishing chicken with cranberry chutney adds flavor and nutrients. Cranberries are rich in fiber and provide vitamin C and potassium.

COURTESY OF U.S. CRANBERRY MARKETING COMMITTEE (D2578-1)

leased 3 to 15 times more PACs than the traditional extraction method, according to the scientists.

The team recommends using the traditional method first—to extract the more readily accessible polyphenols—then following that with the sodium hydroxide-based procedure to tackle the recalcitrant PACs.

The sodium hydroxide method is not new. It is already used to recover polyphenols from rice, wheat, and corn, for instance. But the team is likely the first to show that the process works well for extracting cranberry PACs, too. More research is needed to determine what amounts of PACs are lost as a result of the sodium hydroxide treatment. In the meantime, researchers studying PACs in other plants might want to give the procedure a try. Cranberry PACs are of special interest because some research suggests that they may help counteract urinary tract infections. This role remains controversial, however.

The scientists documented their research in the *Journal of Agricultural and Food Chemistry* and have applied for a patent for the sodium hydroxide-based process.

A Better Way To Measure PACs in Cranberry Products

Prior's investigations of cranberry PACs has also included pinpointing what is perhaps the best available method for commercial labs around the globe to use to reliably determine the PAC content of cranberry products.

Some currently available methods for measuring cranberry PACs either under- or overestimate the levels or pose other problems. Prior and colleagues at five different analytical labs on three continents determined that a quick, inexpensive test, the BL-DMAC (Brunswick Laboratories 4-dimethylaminocinnamaldehyde) assay, provided similar PAC results from one lab to the next. For this research, all of the participating labs were provided with the same set of 11 samples and a known standard as a reference.

"No single test for quantifying cranberry PACs—including this one—is perfect," says Prior. "But we recommend this one as the industry standard for cranberry product PAC analysis worldwide for several reasons. It is fast and inexpensive; provides results that are accurate, reliable, and reproducible; doesn't require expensive equipment or extensive training; and is fairly easy to use."

A peer-reviewed article in the *Journal of the Science of Food and Agriculture* tells more about the research.—By **Marcia Wood,** ARS.

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

To reach the scientists mentioned 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.

ARS scientists closely examined the types and amounts of interesting compounds in cranberry pomace (center), which is the stems, skin, and pulp left over after the berries are pressed to make juice or canned products.

PEGGY GREB (D2569-1)

USDA's History Comes Alive at th

More than 100 white boxes fill shelf after shelf of the fifth floor at the National Agricultural Library (NAL), sheltering secrets of U.S. Department of Agriculture parasite investigations from 1886 to 1987. The boxes are filled with line drawings, photographs, lantern slides, research notes, documents, and correspondence that represent the early history of parasitology work, especially in taxonomy and systematics, conducted over the past 100 years and more by USDA scientists.

Such records are not simply the dry dust of USDA history, but rather a continuing resource for researchers today.

"In these records, we've discovered extensive but preliminary studies of parasites that had not been named," says Agricultural Research Service zoologist Eric P. Hoberg, who is with the ARS Animal Parasitic Diseases Laboratory and is chief curator of the U.S. National Parasite Collection.

The extensive collection of documents and images that makes up the U.S. National Animal Parasite Collection Records at NAL complements the U.S. National Parasite Collection, which is among the largest specimen-based collections in the world.

While the records were originally amassed by the antecedents of the parasitic diseases lab, today NAL has USDA's most effective facilities for preserving such fragile and historically important documents.

These records are important in illuminating the history of parasitology in North America and globally and the history of research conducted on helminth (worms) and arthropod species—mostly ticks—of economic importance in North America, Hoberg explains.

"These records have been central to resolving many issues about the identity and distribution of parasites. For example, the archival material in NAL's collection provided context for the studies that we completed between 2008 and 2010 exploring the diversity of nematode parasites in African ungulates, which established several new genera and described several new species," Hoberg says.

"Particularly important for the scientific papers were the original line drawings that were completed by USDA scientists Willard W. Becklund and M.L. Walker, which were based on collections from Africa that were transferred to Beltsville in the 1960s. We also found detailed line drawings of related specimens that had been borrowed by Becklund from museums in Europe to be very important," Hoberg says.

As a historical record of the progress of research and the changing focus on different priorities, the archive is simply "irreplaceable," Hoberg adds.

The NAL parasitology records are just one of more than 200 collections that NAL holds

U.S. National Animal Parasite Collection Records at NAL include incredibly detailed drawings like this one, of a *Boophilus annulatus* tick, drawn in 1900.

NAL SPECIAL COLLECTIONS (D2575-1)

NAL's parasite collection records also include notable photos like this one from 1893 of USDA's Charles W. Stiles, who discovered American hookworm in humans, establishing that the parasite was endemic and a major health hazard in the South. Up to then, southerners had been tainted with charges of "shiftlessness" and "laziness," but Stiles's discovery showed much of their poor health and physical appearance could be traced to hookworm.

NAL SPECIAL COLLECTIONS (D2573-1)

safe and makes accessible that document the history of many of USDA's programs.

More Than Scientific Literatur

When President Abraham Lincoln signed the act that established the U.S. Department of Agriculture in 1862, the legislation included a call for the creation of a library to gather agricultural information. A year later, with a donation of more than 1,000 volumes of agriculture-related materials from the Agricultural Division of the U.S. Patent Office, the Library of the U.S. Department of Agriculture was born. It became the National Agricultural Library in 1962.

Today, NAL also is the repository for more than just scientific literature and agricultural reports. NAL's special collections encompass correspondence, raw research notes, images, and artifacts, providing a record of how USDA carried out its mission of supporting the nation's agriculture and the international food and fiber supply.

"With access to original materials from the entire research process, scientists can understand how programs developed and even why certain choices were made," says Sara B. Lee, NAL Special Collections librarian. "Scientists can consult the historical record and not reinvent the wheel."

In addition, writers, historians, sociologists, conservationists, and artists regularly turn to the unique records housed in the collections as first-person sources for how USDA events, programs, and policies came about and evolved, Lee adds.

For example, the USDA Pink Bollworm Project Photograph Collection documents USDA work on bollworm detection, prevention, and quarantine measures.

Pink bollworm has been one of the most destructive pests of cotton worldwide and in the United States since it arrived here in the 1920s. USDA control programs began almost immediately and continue today. The Plant Quarantine and Control Administration (later renamed the Bureau of Plant Quarantine), established in 1928, took on responsibility for pink bollworm control. Shifts in the agency in charge of pink bollworm control continued over the years; today the research is with ARS, and the federal regulatory work resides with the Animal and Plant Health Inspection Service.

"All of the historic records of the pink bollworm program might not have been preserved through those shifts, and scientists might have lost the historic reference base that the material represents," Lee explains.

Photographs in the collection show subjects such as the researchers' processes for cleansing the soil of bollworms, the appearance of infested fields, and the effect of bollworms on cotton and other plants.

Plant Hunters

One of the most intriguing historical collections at NAL may be materials from USDA plant explorers. Exploring the world to collect plants that could be beneficial to agriculture was one of USDA's original charges. The department's formal program began in 1898 with a corps of USDA plant explorers who brought back unique varieties of crops and their wild relatives from across the globe.

Many of the journals that these explorers kept of what plants they collected, and from where, are now a treasure trove of information about plant germplasm and are often fascinating reading of botanical adventure.

Special Collections librarian Sara B. Lee selecting fruit and vegetable images from the Rare Book Collection.

PEGGY GREB (D2550-1)

The USDA Pink Bollworm Project Photograph Collection includes this 1917 image of USDA inspector Ivan Shiller, who found the first pink bollworm in the United States in Herne, Texas.

NAL SPECIAL COLLECTIONS (D2577-1)

Notebooks, photos, and other artifacts from USDA plant explorer Frank Meyer, who brought plants from Asia and Europe to the United States from 1898 to 1918.

STEPHEN AUSMUS (K10977-1)

Among the earliest expedition records are photographs and other materials from USDA plant hunter Frank Meyer, whose trips in the early 1900s yielded an amazing variety of more than 2,500 plant specimens from Asia and Europe: crops from apricots and barleys to the first-ever introduction of zoysia grass into the United States.

"These collections provide detailed information about the characteristics and uses of the plants that the explorers found. They also offer fascinating insights into historical agricultural, social, and environmental conditions in remote parts of the world that were rarely documented elsewhere," says ARS botanist Karen Williams, who coordinates the modern-day USDA Plant Exploration Program.

Fiber Collection

Some of the NAL collections go far beyond paper and images. The USDA Fiber Collection contains more than 360 bottled samples of noncotton plant fibers along with thousands of pages of information about plants used for paper, cordage, and textiles. The way it came to be preserved in the NAL Special Collections is typical of the way many of the collections ended up there.

In the early 1900s, Lyster H. Dewey, the USDA botanist in charge of fiber plant investigations, first created the collection called the "Dewey Index." The Dewey Index grew to thousands of index cards and thousands of indexed publications and reprints as USDA fiber specialists researched, traveled, and observed commercial production of fiber and fiber research projects around the world.

When USDA research work began at Arlington Experimental Farm in 1900—now the south parking lot of the Pentagon in Arlington, Virginia—fiber plants were included, and research on them gradually became a greater part of the activity.

In 1965, research on plant fibers other than cotton was discontinued, and those scientists were transferred to other work. All of the records were being kept by researchers in their various offices. The assembled records were moved to NAL in 1984 to ensure their preservation as a unit.

"This is the most complete file of information in this country, if not the world, on fiber crops of the world. Some of the material and information could never be replaced if this collection were lost," wrote Allan K. Stoner, while chair of the ARS Plant Genetics and Germplasm Institute.

PEGGY GREB (D2551-1)

Left: NAL houses about 350 specimens that make up the USDA Fiber Collection.

Apples, Lots of Apples

The USDA Pomological Watercolor Collection at NAL is not only historically important, it is one of the most attractive. These technically accurate images were their day's equivalent of photo documentation of fruits and nuts developed by growers or introduced by USDA around the turn of the 20th century. USDA commissioned watercolor artists from 1886 until 1942, and the collection includes 7,584 paintings, lithographs, and line drawings, created by 21 artists.

A companion collection to the pomology watercolors is the USDA Fruit Laboratory Card Catalog Collection [1850s-1940s]. Among the collection's many documents are the apple history cards, which contain a wide range of information, from locations where different varieties were grown to taste and physical traits.

Some of the apple images and information from the history cards were recently included in an atlas of *Old Southern Apples* by Lee Calhoun, whose second edition was published in 2010.

In the foreword of his first edition, published in 1995, Calhoun wrote: "These cabinets [at NAL] proved to be an astonishing treasure, containing files compiled by the Division of Pomology of the United States Department of Agriculture (USDA) from 1886 to 1920. Here Edith and I found thousands of handwritten cards chronicling the efforts of the Division of Pomology to trace the origins of old apple varieties. Of greatest interest were excerpts of let-

Watercolors like this one (by Royal Charles Steadman, 1922), commissioned by USDA before color photography was common, are now available in digital form at www.nal.usda.gov.

NAL SPECIAL COLLECTIONS (D2572-1)

(D2576-1)

ters written to the USDA by southerners, giving their recollections."

When Calhoun began researching his book in 1988, he expected to find that there had been 300 or 400 different apples grown in the South. Information, much of it from the NAL collections, led Calhoun to eventually document more than 1,800 varieties, many of them no longer being grown today.

Documentation in collections like this, such as where particular varieties were grown and fruit traits and images of varieties that are no longer commonly grown, is an invaluable storehouse of knowledge especially with the growing interest in heirloom varieties, says Susan Fugate, head of NAL Special Collections.

The apple collection has turned out to be very personal for Fugate.

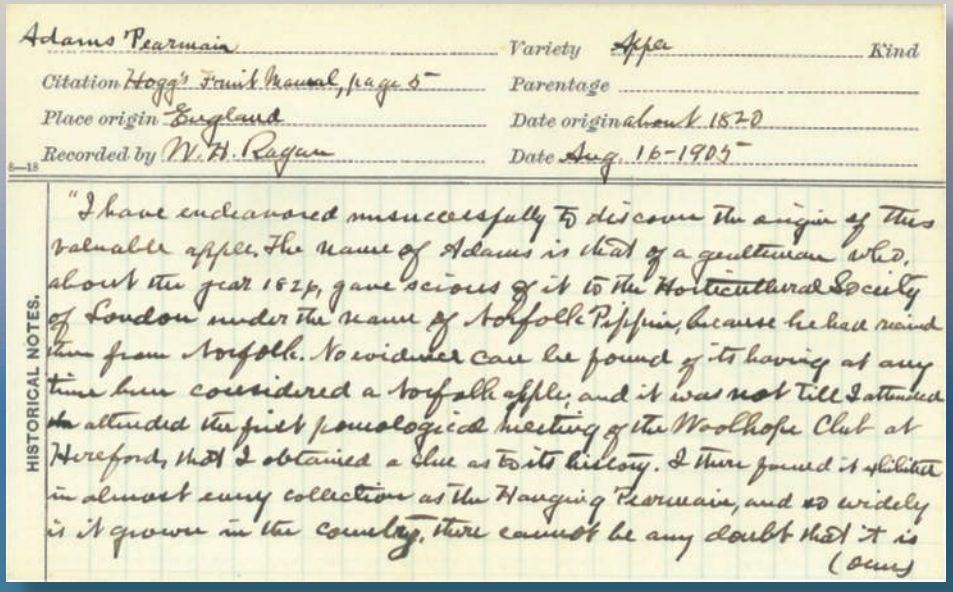
"When Lee Calhoun was here researching for his book, he mentioned references to a Fugate apple variety being grown on the Virginia/Tennessee border," she explains. "In the 1970s, my dad and I visited the farm of his cousin William Fugate, just on the border in Virginia. It had been in the family a long time, and there was an old apple orchard. I wouldn't be surprised if those were Fugate apples."

What the Mall Once Looked Like

The National Agricultural Library's Special Collections is home to a unique collection of drawings and photographs that document the evolution of USDA's buildings on the National Mall from the late 1800s and early 1900s. The images show the lab buildings and greenhouses that used to be there as well the administration buildings that have come and gone.

Below, a photograph (circa 1868) documents the original USDA administration building (left) and the unfinished Washington Monument in the background (center).

NAL conserves the USDA Fruit Laboratory Card Catalog Collection (1850s-1940s). Each card contains details about a variety, such as where it originated and its physical traits.


Adams Pearmain — Variety Apple — Kind
Citation Hogg's Fruit Manual, page 5 — Parentage
Place origin England — Date origin about 1820
Recorded by W. H. Ragan — Date Aug. 16-1905

HISTORICAL NOTES.

"I have endeavored unsuccessfully to discover the origin of this valuable apple. The name of Adams is that of a gentleman who, about the year 1825, gave scions of it to the Horticultural Society of London under the name of Norfolk Pippin, because he had raised them from Norfolk. No evidence can be found of its having at any time been considered a Norfolk apple, and it was not till I attended the attended the first pomological meeting of the Woolhope Club at Hereford, that I obtained a clue as to its history. It there proved identical in almost every collection as the Hanging Pearmain, and so widely is it grown in the country, there cannot be any doubt that it is (over)

NAL SPECIAL COLLECTIONS (D2574-1)

History Meets the Digital Age

Today, NAL is trying to make its historical collections more accessible and usable. As there are funds and manpower, boxes of records are being more clearly indexed, and documents and images are being scanned. You can find the indexes and scanned materials on the NAL Special Collections webpage (specialcollections.nal.usda.gov) by clicking on "Guide to Collections."—By **J. Kim Kaplan,** ARS.

To reach 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.

Predicting Tenderness and Lasting Color

If superior beef tenderness isn't enough to whet your appetite, a system that predicts both beef and pork tenderness as well as color stability in both meats may be something you can sink your teeth into.

In 2001, scientists at the Roman L. Hruska U.S. Meat Animal Research Center (USMARC) in Clay Center, Nebraska, developed a noninvasive tenderness-prediction system to identify U.S. Select beef carcasses with exceptional tenderness in the ribeye/strip loin muscle. The process, which doesn't require cooking or tasting, is based on visible and near-infrared reflectance (Vis/NIR) spectroscopy.

Though the system is commonly referred to as the "USMARC Noninvasive Beef Tenderness Prediction System," the name no longer describes its many applications. Food technologists Tommy Wheeler, Steven Shackelford, and Andy King in the USMARC Meat Safety and Quality Research Unit have shown that it is equally effective at predicting more than just tenderness—and in pork as well as beef.

Beefing Up Technology

Vis/NIR spectroscopy had been used as early as the 1950s to evaluate agricultural and other products, and it appeared to be ideal for developing technology that could predict meat tenderness without destroying valuable parts of the carcass.

"We started looking at a way to use Vis/NIR to evaluate beef—something that could operate at a rate of 400 carcasses per hour," Shackelford says. "We found a portable commercial instrument, developed repeatable ways to apply it to meat products, and then started testing its ability to predict tenderness."

The research quickly garnered collaborations with beef-processing companies and the National Cattlemen's Beef Association (NCBA), which provided grants for studies from Beef Checkoff funds.

Over the last several years, scientists have further validated their models by testing the system on more than 4,000 carcasses during grading at processing facilities.

In a recent Checkoff-funded study, Vis/NIR evaluation was conducted on the ribeye during grading, on various muscles as the carcass was cut up, and on steaks cut after aging 14 days. This study demonstrated that the technology could predict tenderness of the ribeye during carcass grading as well as the tenderness of most other major cuts of meat. It also showed that downstream processors or steak cutters could apply the technology to individual cuts of meat or steaks after aging.

"Most U.S. Select-grade beef is tender, but it's often sold at a discount relative to U.S. Choice-grade beef," Shackelford says. "This technology allows packing companies to identify U.S. Select carcasses that excel in tenderness."

Bridget Wasser, NCBA senior director of Meat Science and Technology, agrees that the industry could use technology like this to deliver more consistent beef products to the supply chain and consumers.

"Prediction of cooked-beef tenderness from raw-beef evaluation should allow industry to better funnel beef products to their best end use," she says. "Those predicted to be most tender could be valued and marketed as such."

One commercial company has implemented the technology to ensure the tenderness of its branded line of beef products.

Finding Succulent Pork Chops

What applies to beef doesn't necessarily apply to pork, but in the case of the USMARC tenderness-prediction technology, it can. Scientists have been able to modify the technique to predict pork loin tenderness.

"The pork application is a little different than beef," Shackelford says. "The way beef is presented for grading provides an opportunity to make measurements on the cross section of the loin muscle. You don't have that in pork."

With this in mind, Shackelford and his colleagues developed computer models specifically for noninvasive prediction of pork loin tenderness. By working with representatives from the National Pork Board (NPB) and other industry collaborators, they were able to successfully adapt the system and test it on pork loins at several pork-processing plants.

DAY 1 STEVEN SHACKELFORD (D2585-1)

DAY 6 STEVEN SHACKELFORD (D2587-1)

DAY 9 STEVEN SHACKELFORD (D2588-1)

Beef steak color changes during simulated retail display testing.

To validate the technology, 1,800 boneless pork loins were evaluated with Vis/NIR during the boning and trimming process at commercial plants. Samples from cooked pork chops were tested and classified using slice shear force, a measure of tenderness.

"Recent NPB research has identified shear force as the predominant known factor determining pork-eating quality," says Mark Knauer, former NPB animal science director. "Therefore, successful development of a noninvasive tenderness-prediction system would allow the pork industry to develop guaranteed-tender products and improve pork-eating quality."

If the technology is adopted by the industry, product differentiation and improved genetic selection will be possible, he adds.

Color Meat Bright Red

Color is important to shoppers who consider bright-red beef or bright-pink pork as a mark of freshness and quality. But some steaks and chops turn brown earlier than others, and those might not be bought, even though they're still good.

"Only the color chemistry has changed, so it's no longer bright red or pink," Wheeler says.

"In a best-case scenario, less appealing steaks are sold at a lesser price," King says. "In a worst-case scenario, they're thrown away. Either way, that's a substantial loss."

Some research suggested that color-stability problems are mostly environmental—citing light, temperature, and packaging as major contributors to discoloration—and have little to do with animal-to-animal variation. But the USMARC team was able to show that some cattle produce beef with better color stability.

"We knew the pedigrees of these 500 animals, so we were able to attribute how much of this variation in color was due to genetics. What started out as a study to find out whether variation in color stability was strictly due to environmental factors resulted in a multi-faceted approach to influence color stability," King says.

Studies involved placing steaks in simulated retail-display conditions and evaluating the two main biochemical mechanisms associated with variation in lean color stability—oxygen consumption (high consumption leads to browning) and metmyoglobin-reducing activity (high levels keep meat red). Metmyoglobin is responsible for the brown coloration that occurs as meat ages.

"We concluded that there were substantial differences across animals in color stability and that there were genetic components that should make it possible to improve stability through genetic selection," King says. "In addition, we developed models using the Vis/NIR technology that would allow companies to identify beef and pork suitable for retail markets that require a long color life."

Research suggests that the multifaceted technology can be used efficiently and cost-effectively to control and manage variation in tenderness and color stability for beef as well as pork, Shackelford says. More research is under way to further evaluate and validate its many applications.—By **Sandra Avant,** ARS.

This research is part of Food Animal Production, an ARS national program (#101) described at www.nps.ars.usda.gov.

STEVEN SHACKELFORD (2589-1)

A visible and near-infrared reflectance (Vis/NIR) spectroscopy probe head is applied to a top sirloin steak to predict tenderness and color stability.

To reach scientists mentioned in this article, contact Sandra Avant, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1627, sandra.avant@ars.usda.gov.

Meat color is important to shoppers who consider bright-red beef or bright-pink pork as a mark of freshness and quality. ARS scientists have developed models using Vis/NIR technology that allow companies to identify beef and pork suitable for retail markets.

STEPHEN AUSMUS (D2590-1)

Roundworms (and Their Bacterial Buddies) Rub Out Pests

Roundworms, microscopic wormlike organisms also known as "nematodes," can be friend, foe, or something in between. Some species are parasitic, dependent on hosts—plant, animal, insect, or human—to survive. Others are stealthy predators, prowling soils and other hunting grounds for bacteria, fungi, and other microbial prey—or sometimes ambushing them.

Lynn Carta and colleagues at the Agricultural Research Service's Nematology Laboratory in Beltsville, Maryland, are among the world's foremost authorities on nematodes and have developed sophisticated tools and techniques for studying their morphological, biochemical, and genetic features in unprecedented detail.

Not surprisingly, the lab's services are in high demand, especially from regulatory agencies tasked with safeguarding U.S. agriculture from the entry of exotic pathogens and pests, such as the pale cyst nematode, *Globodera pallida*, which damages potato, tomato, and other crops.

The ARS lab's expertise is also critical to research aimed at harnessing beneficial species of insect-killing (entomopathogenic) nematodes as biocontrol agents, which can be commercially formulated as an alternative to synthetic pesticides.

Casting About for New Talent

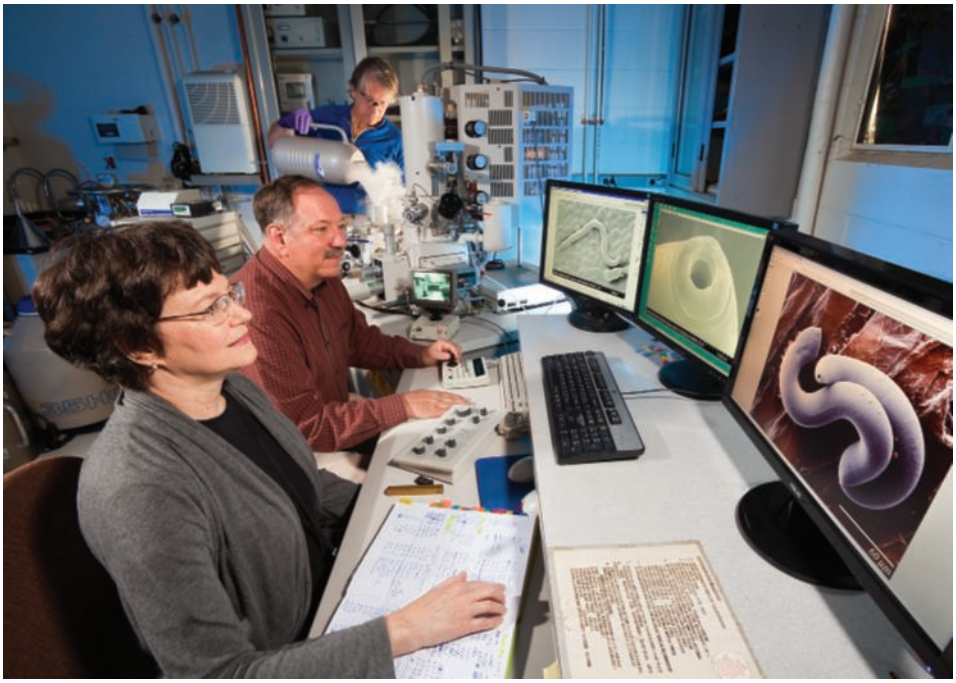
Lately, Carta has focused attention on identifying and describing nematodes that have potential as biological controls for Formosan subterranean termites, a nonnative species whose appetite for cellulose—whether it be the heartwood of trees or the wooden support beams of buildings—causes an estimated $1 billion annually in damages, repairs, and controls.

Since 1999, Carta has determined the identities of seven nematode species isolated from the bodies of Formosan termites by Ashok Raina, a retired entomologist formerly with ARS's Southern Regional Research Center in New Orleans, Louisiana. Other specimens Carta has identified were collected from more exotic locales, including rural sites in Uzbekistan, where collaborators found species of *Pelodera* nematodes in the heads, abdomens, and legs of dead or sick Turkestan termites. The team reported its findings in the December 2010 issue of the *International Journal of Nematology*.

"Common entomopathogenic nematodes don't kill invasive Formosan termites efficiently," notes Carta. Thus, more virulent species are sought, and so are symbiotic microorganisms, such as bacteria, that can assist in killing the termites or other insect hosts. The *Pelodera* nematodes are of interest "because of their association with significant sickness and mortality in termites in Uzbekistan," she says.

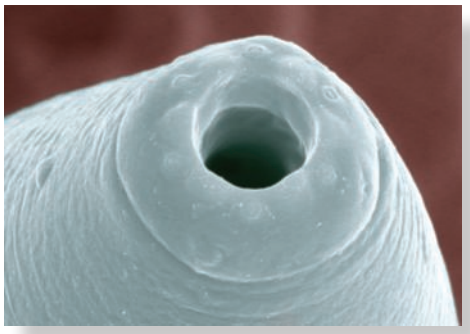
A *Poikilolaimus* nematode species that Raina collected in Louisiana is also of in-

Plant pathologist Lynn Carta (left) and Gary Bauchan (center), director of the Electron and Confocal Microscopy Unit, use a low-temperature scanning electron microscope to view nematode anatomical structures useful for species identification. In the background, support scientist Charlie Murphy adds liquid nitrogen, which is used to preserve the specimens at very cold temperatures.



STEPHEN AUSMUS (D2540-6)

Mouth parts of a *Parasitorhabditis frontali* nematode. Image courtesy of Lynn Carta and Gary Bauchan; colorization by Stephen Ausmus.



(D2547-1)

terest. His early experiments showed that this nematode species invades the heads of Formosan termites and that a bacterial accomplice probably sickened the insects in the field. The bacteria, which were identified by ARS microbiologist Phyllis Martin, are known to excrete trace amounts of cyanide. But whether this played a role in the termite's deaths has yet to be determined. "We did not identify the bacterium from the termite itself, but only found it with the nematode," says Carta.

Still, the bacterial association raises an interesting prospect: using nematodes as vectors of insect pathogens rather than as primary biocontrol agents—the traditional approach. Applied to the soil, for example, the nematodes would find, penetrate, and then infest their targeted insect hosts with lethal doses of entomopathogenic bacteria.

Setting the Stage

That such approaches can even be considered is a credit to the wealth of information resulting from studies by Carta and colleagues. This includes meticulous drawings that identify parts of nematodes—including their mouth and tail features—determinations of their host range and nature of their associations, geographic distribution, taxonomic groupings, genetic sequences, and other data.

It also helps to have high-tech tools handy, including a scanning electron microscope (SEM), which uses special sensors and an electron beam to produce images of specimens that far surpass what can be achieved with standard light microscopes. Eric Erbe and William Wergin, both retired and formerly with ARS's Electron and Confocal Microscopy Unit (ECMU) in Beltsville, Maryland, are among those Carta credits with assisting in her investigations. She also credits Gary Bauchan, who now directs research at ECMU.

Carta's recent SEM-aided collaborations include working with a team of researchers led by Cetin Yuceer from Mississippi State University and including scientists from the University of Chicago, Davidson College, Hendrix College, and the USDA Forest Service to identify a new nematode species that's associated with the southern pine beetle, *Dendroctonus frontalis*.

The 1/8-inch-long beetle is a pest of coniferous forests mainly in the southeastern United States. Outbreaks are sporadic, but can be costly. For example, an outbreak from 1992 to 1993 on nearly 3,000 acres in Maryland destroyed 20 million board feet of loblolly pine, according to the state's Department of Natural Resources.

The researchers' studies suggest the nematode is a new species of *Parasitorhabditis*—similar to those found infesting beetles in parts of Texas, New York, and Germany. Besides its taxonomic significance, the nematode's discovery may shed further light on the pest's ecological role and success, as well as expose vulnerabilities that could be exploited.

Oh, What a Tangled Web…

Carta's sleuthing has also helped finger a nematode-microbe duo in the deaths of pet tarantulas. The nematode, a *Panagrellus* species, apparently harms the spider only in captivity. The nematode is suspected of being present in some insects fed to tarantulas, including mealworms, the larval stage of a bark beetle. Once inside the tarantula's mouth, the nematode wriggles into the spider's head, feeding on its brain and eventually killing it. Carta believes a yeast is also involved. She is intrigued by the possibility, because it would reveal a new ecological association that could yield novel approaches to pest control.

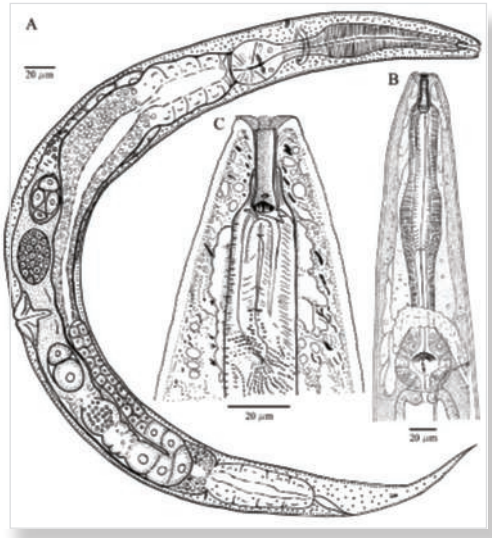
On another front, nematology research like Carta's may have direct bearing on the well-being of soils and plants. Applying commercially formulated bacteria to kill root-damaging nematodes or fungi, for example, can also harm nontarget species that help with nutrient recycling. Conversely, species of bacteria-feeding nematodes that occur in soils may prey on commercially formulated bacteria that have been applied, possibly reducing *their* biocontrol effectiveness.

The subterranean world in which nematodes operate is complex and interwoven. Knowledge gained from studies by Carta and others is improving our understanding—as well as use, management, and appreciation of—these ubiquitous organisms.—By **Jan Suszkiw,** ARS.

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

Lynn Carta is with the USDA-ARS Nematology Laboratory, 10300 Baltimore Ave., Bldg. 010A, Room 110, Beltsville, MD 20705-2350; (301) 504-8787, lynn.carta@ars.usda.gov.

Meticulous drawings such as this one by Lynn Carta were used to describe *Rhabditis (Metarhabditis) rainai.*



LYNN CARTA (D2541-1)

Rhabditis (Metarhabditis) rainai, a potential biocontrol agent against Formosan termites.

LYNN CARTA (D2546-1)

A Formosan subterranean termite soldier.

SCOTT BAUER (K8085-3)

Understanding Herbicide Resistance of an Enzyme in the "Pigments of Life"

STEPHEN AUSMUS (D2542-8)

At the ARS Natural Products Utilization Research Unit in Oxford, Mississippi, support scientist Susan Watson extracts a sample of pigments from leaf tissue for high-performance liquid chromatography analysis by plant physiologist Franck Dayan.

An Agricultural Research Service scientist in Oxford, Mississippi, is working toward developing new herbicides by focusing on a molecular pathway that not only controls weeds in soybean fields, but might also have helped shape our nation's history.

Franck Dayan, a plant physiologist with the ARS Natural Products Utilization Research Unit in Oxford, is an expert on a class of weed killers known as "PPO herbicides," which choke off the weed's ability to make chlorophyll. His efforts are increasingly important because weeds are beginning to develop resistance to glyphosate, the world's most widely used herbicide, and alternatives are needed.

Much of Dayan's work focuses on a class of ring-shaped pigment molecules known as porphyrins (pronounced *POR-fer-ins*) that "bind" or react with different metals and perform vital functions in both plants and animals. Chlorophyll is a porphyrin that binds magnesium, giving plants their green pigment and playing a pivotal role in photosynthesis. Heme is a porphyrin that binds iron as an essential step in supplying oxygen to animal blood cells.

One of the key steps in porphyrin synthesis is performed by an enzyme (protoporphyrinogen oxidase, or PPO), and its disruption can cause problems in plants and animals. In humans, disruption of the PPO enzyme is associated with a congenital disease known as "porphyria," with symptoms that may include light sensitivity, seizures, and neuropsychiatric problems. Scholars have argued that a case of porphyria in King George III may have contributed to the colonies' struggle for independence. (See sidebar.)

In plants, PPO herbicides work by disrupting the enzyme's production of porphyrins, causing harm to the plant. PPO herbicides have been around for almost 40 years and are specifically designed so that they only disrupt PPO enzyme activity in plants and not in humans. "With these herbicides, we are able to intentionally and specifically disrupt plant PPO enzyme activity and do it in a way that cannot possibly have any effect on enzyme activity in humans," Dayan says.

STEPHEN AUSMUS (D2544-3)

Franck Dayan observes wild-type and herbicide-resistant biotypes of pigweed (Palmer Amaranth) as Mississippi State University graduate student Daniela Ribeiro collects plant samples for DNA analysis.

Dayan recently published a report on the molecular mechanism that can trigger resistance to PPO herbicides in a common weed. Understanding the resistance mechanism should lead to better herbicides.

Working in the Weeds

Since the mid-1990s, glyphosate use in crop fields has been so successful that interest in research and development of alternative weed killers had been on the wane. Many experts considered it too difficult to come up with an herbicide that could match glyphosate for cost and effectiveness, Dayan says. But with weeds developing resistance to glyphosate, interest in PPO herbicides is picking up. Herbicides have also become essential tools in modern agriculture, increasing the ability to control weeds to a point where growers are better able to adopt environmentally friendly practices, such as no-till cropping systems.

"Glyphosate still plays a dominant role in weed control in soybeans and other crops, but with glyphosate resistance, there is renewed interest in herbicides that inhibit the PPO enzyme," Dayan says.

Scientists recently showed that waterhemp *(Amaranthus tuberculatus),* a common weed, developed resistance to PPO herbicides by deleting an amino acid known as "glycine 210" from the PPO enzyme. Such an evolutionary mechanism is unusual. Enzymes and proteins are made up of amino acids, but when a plant develops resistance to a weed killer, it is usually because one amino acid in an enzyme is substituted for another—not deleted. "This was the first time that resistance caused by a deletion was ever seen," Dayan says.

Dayan examined the consequences of this amino acid deletion on the PPO enzyme by conducting protein-modeling studies of waterhemp. "The question was, How did the deletion of this amino acid allow the plant to become resistant?" says Dayan.

To find the answer, he and his colleagues overlaid the genetic sequence of the enzyme in the resistant waterhemp plants on the genetic sequence of a related enzyme that has a known structure, in this case, the PPO enzyme from tobacco plants. They also compared the molecular structure of enzymes from PPO-susceptible waterhemp to the structure of enzymes from resistant waterhemp. Using that information, they developed a computer-generated, three-dimensional version of the enzyme in the resistant plant.

The work, published in the journal *Biochimica et Biophysica Acta,* confirmed that an evolutionary change in a single enzyme—the deletion of an amino acid—caused structural changes in the enzyme-binding site and allowed waterhemp to become resistant to the herbicide. While the structural changes were too insignificant to affect most of the plant's physiological functions, they did disrupt the PPO enzyme production of porphyrins and caused the enzyme-binding site to become enlarged so that the herbicide did not bind as well.

"The place where the herbicide binds on the enzyme is a key," Dayan says. Knowing the shape of the binding site will help scientists design herbicides with a different shape that would bind more effectively.

Understanding porphyrins has a practical benefit because of their role in the development of herbicides. But the ubiquitous presence of these ring-shaped molecules, Dayan says, serves as an example of the unified nature of life on Earth. In an article coauthored with his daughter, Emilie Dayan, and published in the May-June 2011 issue of *American Scientist,* he writes, "They attract little attention, but you find them throughout the plant and the animal kingdom, and life couldn't exist without them."—By **Dennis O'Brien,** ARS.

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

Franck Dayan is in the USDA-ARS Natural Products Utilization Research Unit, Room 2012, University of Mississippi, Oxford, MS 38677; (662) 915-1039, franck.dayan@ars.usda.gov.

King George's Porphyrin Problem

Disruption of the PPO enzyme in humans is rare but is known to cause porphyria, a group of congenital diseases that in one form, known as "variegate porphyria," can cause symptoms that include temporary paralysis of limbs, sensitivity to light, seizures, hallucinations, and other neuropsychiatric problems. Symptoms can appear intermittently throughout someone's life.

Agricultural Research Service plant physiologist Franck Dayan notes in *American Scientist* that porphyrins form pathways that "serve as the assembly line for the most abundant pigments in nature." Because pigments are involved, people with porphyria may also excrete purplish tint in the urine and feces.

Dayan recounts how several experts have found historical evidence that King George III, monarch of England from 1760 until his death in 1820, had the disease, periodically suffering from abdominal pains, paralysis of the arms and legs, wine-colored urine, and psychiatric problems that eventually forced him into confinement. Some experts have argued that the American Revolution may be partially attributed to the king's illness because it contributed to his stubbornness in dealing with the colonies.

The king's illness was portrayed in the 1994 film, "The Madness of King George."

A "Greener" Fertilizer for Growing Horticultural Crops

Plants require certain elements for normal growth, including small amounts of micronutrients like iron, manganese, copper, and zinc. Fertilizers that provide these micronutrients often include certain synthetically produced organic compounds known as "chelating agents," raising concerns about whether their runoff into waterways increases levels of heavy metals.

An Agricultural Research Service scientist with the U.S. Horticultural Research Laboratory (USHRL), in Fort Pierce, Florida, is testing a relatively new, natural, and "greener" chelating agent as an alternative to the synthetic ones.

To make sure plants take up sufficient quantities of the micronutrients they need, growers use fertilizers formulated with chelating agents. These compounds bind with the micronutrients so they are available in the root zone. "Chelating agents also allow growers to maintain concentrated fertilizer stock solutions that contain soluble micronutrients. Growers can dilute these solutions and inject nutrients into their irrigation water," says horticulturalist Joseph Albano.

The effectiveness of a chelating agent to supply micronutrients to the plant is a balancing act that depends on soil or potting mix pH level. If the pH is too high, the metals become insoluble and are unavailable to the plant, even with the use of chelating agents, and this leads to nutrient-deficiency disorders. If pH is too low, metals become soluble, and in combination with chelating agents, they may become toxic. Marigolds, vinca, impatiens, and geraniums are particularly susceptible to nutrient disorders caused by iron and manganese toxicity, referred to as "bronze speckle" or "micronutrient toxicity syndrome." Symptoms of the syndrome can vary, but leaves of affected plants often develop chlorotic (yellowing) and necrotic (dead tissue) speckling that can progress to total leaf necrosis. The development of this disorder greatly decreases the value of ornamental plants.

EDTA and DTPA are the most common chelating agents used in formulating soluble fertilizers for floral and nursery crop production because they can "deliver" micronutrients within the recommended pH range for growing most of these crops. But they pose problems. When complexed with iron and exposed to sunlight, they degrade quickly, so growers need to store chelate-containing fertilizers in opaque containers. A more pressing concern, though, is that they are not readily biodegradable and persist in the environment for some time. They can also extract metals from sediments, and their use is believed to add to the amounts of iron and other heavy metals in waterways. EDTA is a particularly popular chelating agent and is used in many industrial processes and municipal products in addition to horticultural fertilizers. But concerns about its use in Europe have prompted calls there for the use of alternatives whenever possible.

Albano thinks he has found a "green" alternative for U.S. growers. Known as "EDDS," the chelating agent is just as effective as EDTA and DTPA at delivering micronutrients to plant roots. But EDDS is biodegradable, meaning that it will not persist in the environment and thus is less likely to take up and transport heavy metals in soils and waterways. EDDS is "gaining favor in Europe because it degrades in weeks as opposed to months," Albano says.

In a series of greenhouse studies, Albano grew marigolds for 47 days in containers filled with standard soil-less potting media. He used fertilizers formulated with EDDS, EDTA, or DTPA. Each of the three treatments was chelated with iron so that Albano could assess how much iron the marigolds were taking up, their overall health and growth patterns, and how quickly the iron-chelates degraded when exposed to light.

The results showed that iron-EDDS degraded more quickly when exposed to light, but that there were no significant differences in plant health, growth patterns, or in the micronutrient levels found in plant tissue. The report, published in *HortScience,* was the first peer-reviewed study to evaluate EDDS as a chelating agent in fertilizers used on a horticultural crop, Albano says. He has also coauthored a chapter on chelating agents in a book on best management practices for container-grown horticultural crops. The work is expected to encourage use of EDDS as an environmentally friendly chelating agent in formulating fertilizers used in the production of floral and nursery crops.—By **Dennis O'Brien,** ARS.

The research is part of Crop Production (#305) and Water Availability and Watershed Management (#211), two ARS national programs described at www.nps.ars.usda.gov.

Joseph Albano is with the U.S. Horticultural Research Laboratory, 2001 South Rock Rd., Fort Pierce, FL 34945; (772) 462-5939, joseph.albano@ars.usda.gov.

STEPHEN AUSMUS (D2565-2)

Horticulturist Joseph Albano (right) measures chlorophyll levels in leaves of marigolds treated with the chelating agent EDDS, and technician Chris Lasser measures iron levels in iron chelate samples.

The Agricultural Research Service has labs all over the country.

Locations Featured in This Magazine Issue

Locations listed west to east.

Pullman, Washington
6 research units ■ 136 employees

U.S. Arid-Land Agricultural Research Center, Maricopa, Arizona
3 research units ■ 79 employees

Las Cruces, New Mexico
2 research units ■ 48 employees

Fort Collins, Colorado
7 research units ■ 141 employees

Akron, Colorado
1 research unit ■ 28 employees

Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska
6 research units ■ 113 employees

Little Rock, Arkansas
9 research units ■ 67 employees (5 ARS employees, 62 university employees)

Southern Regional Research Center, New Orleans, Louisiana
7 research units ■ 181 employees

Oxford, Mississippi
3 research units ■ 102 employees

Thad Cochran Southern Horticulture Laboratory, Poplarville, Mississippi
1 research unit ■ 38 employees

U.S. Horticultural Research Laboratory, Fort Pierce, Florida
4 research units ■ 148 employees

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

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

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