South Atlantic Area Fiscal Year 2008 Research Highlights

United States Department of Agriculture
Agricultural Research Service

Foreword

In the following pages you will find articles about the work of the Agricultural Research Service (ARS) in its South Atlantic Area. You may not be familiar with us, so let us take this opportunity to introduce you to ARS, the principal in-house research agency of the U.S. Department of Agriculture (USDA).

Congress first authorized federally supported agricultural research in the Organic Act of 1862, establishing what is now USDA. That statute directed the Commissioner of Agriculture "to acquire and preserve in his Department all information he can obtain by means of books and correspondence, and by practical and scientific experiments."

The scope of USDA's agricultural research programs extends far beyond Congress's vision of 1862. Today, agricultural research has a direct impact on nearly all aspects of modem life. Our scientists not only study crops and livestock to improve quality and quantity but they also devise new ways of using those crops to add value to our lives, increase exports, improve human health, and protect the environment.

We in ARS, like all Americans, are very concerned about safe and nutritious food. We study the bugs that cause foodborne illness and find ways to reduce or eliminate unwanted pests from the food supply. If agricultural problems arise, such as a new disease of crops or livestock, we have the capacity to respond rapidly to find safe and appropriate solutions.

We care deeply about the environment. Extensive programs in the ARS South Atlantic Area focus on preserving and improving soil, air, and water quality. We are finding new and innovative ways to manage animal wastes, prevent soil erosion, and eliminate pesticides from surface water and groundwater.

These examples represent only a few of the ARS research programs dedicated to maintaining and enhancing the economic strength of U.S. agriculture, while improving the quality of life for every American. In this volume you will find some facts about the South Atlantic Area, a list of the research units, where they are located, and the people you can contact for further information. We are delighted that you are reviewing this volume and hope that you will find the articles useful and interesting. Please let us know if we can be of service to you.

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Contents

GREAT Guava!

PEGGY GREB (D890-1)

Guava, the juicy, pink, sliced fruit in the center, is high in antioxidants.

Tropical fruits offer nutrition—along with color, taste, and variety.

For years, there's been a common notion that you get the best nutritional punch from a few well-publicized foods, such as blueberries, black beans, and broccoli. Well, they can move over now and make room for a surprising new addition: guava.

Until recently, only limited information has been available about the nutritional composition of tropical fruits—especially the more exotic ones. But in south Florida, growers are not only producing guava, carambola, mango, papaya, and citrus, but also pitaya, sapodilla, lychee, longan, and mamey sapote. So researchers at the U.S. Citrus and Subtropical Products Research Laboratory at Winter Haven, Florida, have been using standard methods to analyze these fruits for components that could be beneficial to human health.

Heading the effort is the lab's research leader, horticulturist Liz Baldwin, with ARS scientists John Manthey, Gary Luzio, Anne Plotto, Jan Narciso, and Kevin Goodner and research associate Kanjana Mahattanatawee, in collaboration with scientists at the University of Florida's Citrus Research and Education Center in Lake Alfred. They're also cooperating with researchers at Siam University in Bangkok and Chiang Mai University, both in Thailand, where some non-Florida native variations of these same fruits are available for testing. At the lab, they are analyzing all these fruits for phytonutrients, flavor, and several other components.

Rich in Antioxidants

The function of natural antioxidants and dietary fiber in foods and biological systems has received a lot of attention lately. Fruits and vegetables are playing an increasingly significant role in the daily diet, because many of them provide an optimal mix of antioxidants—such as vitamins C and E, polyphenols, and carotenoids—along with complex carbohydrates and fiber.

Antioxidants are plant chemicals that have the power to neutralize free radicals, which are harmful compounds that are both generated inside human bodies and found in pollutants like cigarette smoke. Reducing free radicals can only improve human health because the oxidative damage they cause to human cells is believed to trigger various chronic diseases. Free-radical damage has been linked to cancer, Alzheimer's disease, rheumatoid arthritis, cardiovascular disease, cataracts, age-related macular degeneration—and to the aging process itself.

It's no wonder that nutritionists and scientists have—for years—recommended that we eat five to nine servings of fruits and vegetables each day.

Food writers and marketers have been emphasizing foods known to be high in antioxidants—adding chocolate, oats, onions, soy, spinach, sweet potatoes, tomatoes, and walnuts to the list. The Winter Haven scientists have gone in search of even more high-antioxidant options.

"These specialty tropical fruits are delicious and pack a nutritional punch," said Baldwin. "They're a great addition to a healthy diet."

PEGGY GREB (D893-1)

Technician Holly Sisson (left) and horticulturist Elizabeth Baldwin homogenize guava for antioxidant and pigment analyses.

Getting at the Good Stuff

Using a variety of methods to analyze for individual nutrients, the researchers have shown that carambola (star fruit), red pitaya (also known as "red dragon"), and mamey sapote are all high in antioxidant compounds called "phenolics," and mamey sapote is also high in fiber. But the one fruit that beats them all is guava. It had the highest antioxidant potential (measured as ORAC values), total phenolics, vitamin C, and dietary fiber.

ORAC—or oxygen radical absorbance capacity—is a measure of the ability of foods and other compounds to subdue oxygen free radicals. The higher the ORAC value of a food, the more antioxidant power it contains. This is measured by using a 96-well fluorescence microplate reader—an advanced device with high sensitivity and the ability to carry out kinetic studies, such as this one, which require that many ORAC assays be run simultaneously.

Guava's antioxidant content proved to be around that of orange, grapefruit, and broccoli, and just below that of spinach—all foods that are considered to be high in antioxidants. Other fruits that ranked surprisingly high in antioxidants included lychee and papaya. More detailed results were published in a 2006 issue of the *Journal of Agricultural and Food Chemistry.*

A grant from the Tropical Fruit Growers of South Florida helped fund this research.—By **Alfredo Flores,** ARS.

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

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U.S.-Thai Exchange Bolsters Coatings Research

ARS horticulturist Liz Baldwin, plant physiologist Anne Plotto, microbiologist Jan Narciso, and Thai collaborators are developing coatings and surface treatments to maintain the red color of lychee fruit and protect fresh-cut mango.

Most of the work has been done through a collaboration that began with Nithiya Rattanapanone, who is with the Faculty of Agro-Industry at Chiang Mai University (CMU). Rattanapanone first visited the U.S. Citrus and Subtropical Products Research Laboratory (USCSPL) in Winter Haven, Florida, in 2003. That was the start of a mutually beneficial partnership between ARS and Thai scientists. In 2004, Baldwin visited CMU to give a workshop on edible coatings for fruits and vegetables and to work on developing coatings for cut mango.

For 3 months in 2005, Usawadee Chanasut, a professor with the Postharvest Technology Institute at CMU, and ARS chemist John Manthey worked together at Winter Haven to determine the antioxidant potential of Thai eggplant. Chanasut is now finishing that study in Thailand.

In 2005 and 2006, Rattanapanone returned to Winter Haven to compare results from experiments there and in Thailand on edible coatings and other surface treatments for reducing browning of lychee peel. Several of Rattanapanone's students have visited USCSPL to work on their doctoral thesis research.

"We've been very happy with our partnership with these universities in Thailand," says Baldwin. "It has been very productive and has yielded information that is relevant to the tropical fruit industry here in south Florida. We are expecting to write at least four or five publications on this cooperative international research effort."

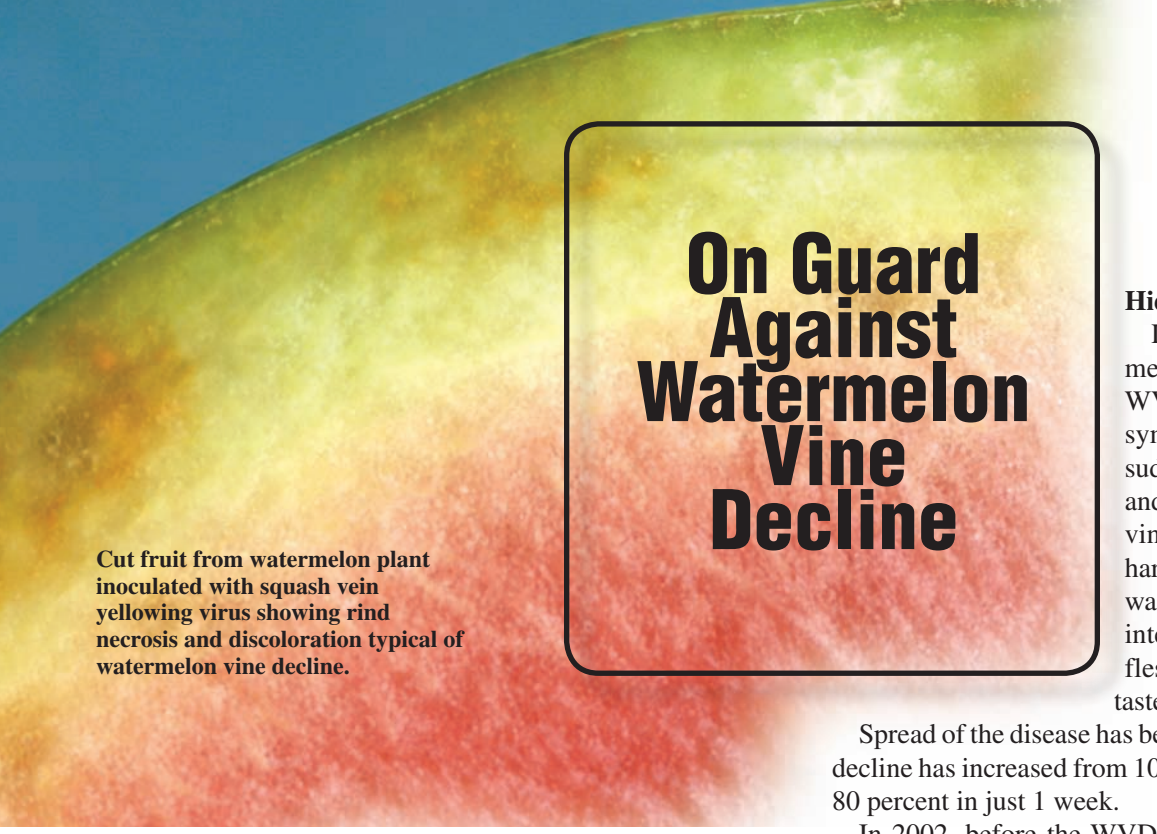
One of USCSPL's former postdoctoral associates has joined the faculty at Siam University. Kanjana Mahattanatawee worked on tropical fruit flavor and phenolic compounds while at Winter Haven and is now continuing this research at Siam University. She plans to return to Winter Haven this year for further collaborative studies.—By **Alfredo Flores,** ARS.

PEGGY GREB (D891-1)

PEGGY GREB (D892-1)

Technician Christopher Ference (above left) sanitizes a whole mango before cutting it into pieces while technician Keith Williamson dips the mango pieces in an edible coating (at right) designed to prolong the cut fruit's shelf life.

On Guard Against Watermelon Vine Decline



Cut fruit from watermelon plant inoculated with squash vein yellowing virus showing rind necrosis and discoloration typical of watermelon vine decline.

SCOTT ADKINS (D947-1)

Deep in winter, we dream of summertime and delicious outdoor picnics filled with hot dogs, lemonade, and refreshing watermelon. But the availability of that popular, nutritious fruit could be drastically affected by a looming new threat.

Watermelon vine decline—or WVD—is a crippling disease of watermelon that has made a serious economic impact since first being seen in Florida in May 2003. So far, it has been limited to the Sunshine State, but commercial watermelon growers fear that it could spread to other states.

Research efforts led by plant pathologist Scott Adkins at the ARS Subtropical Plant Pathology Research Unit in Fort Pierce, Florida, have focused on pinpointing the cause of the disease and finding ways to curb it.

STEPHEN AUSMUS (D288-4)

A pair of silverleaf whiteflies, *Bemisia tabaci,* which measure about one-tenth of an inch long, feed on a watermelon leaf.

Hidden Menace

Looks are deceiving when watermelons first come under attack by WVD because there are no external symptoms on the fruit itself. Then, suddenly, there's wilting, browning, and loss of leaves, followed by rapid vine collapse and death just before harvest. While the outside of infected watermelons may appear normal, the interior often shows browning. The flesh appears greasy and has a bad taste, making the fruit unmarketable.

Spread of the disease has been very rapid. In some fields, vine decline has increased from 10 percent of the plants to more than 80 percent in just 1 week.

In 2002, before the WVD assault, Florida was ranked first in watermelon production, with 15 percent of U.S. watermelon acreage and 19 percent of total production and value. Since spring 2003, WVD has afflicted sections of southwest Florida and has moved into west-central Florida. In spring 2004, some growers lost more than half their harvest, and others have since lost their entire fields.

In fact, damage and yield losses exceeded $60 million in 2005 alone, further driving interest in WVD research. As a result of the declining output, Florida has relinquished its number-one spot to Texas.

"The disease has been so severe and caused such economic losses that Florida watermelon farmers have been seriously considering switching to other crops," says Adkins.

First, Find the Culprit

Nonbiological factors, bacteria, and fungi had been eliminated as the cause of WVD by other researchers. Then Adkins—in collaboration with Susan Webb, a University of Florida (UFL) entomologist, and Carlye Baker, a plant pathologist with the Florida Department of Agriculture and Consumer Services, Division of Plant Industry—found that the cause is a new virus known as "squash vein yellowing virus" (SqVYV). The SqVYV seems to infect plants in only the Cucurbitaceae family, with the most dramatic symptoms occurring on squash and watermelon.

It had been known for some time that the principal insect pests on watermelons in Florida were aphids, rindworms, whiteflies, and thrips, but it took 2 years of research to realize that SqVYV transmitted by the silverleaf whitefly, *Bemisia tabaci,* was responsible for WVD.

This research involved both extensive molecular lab analyses of the virus under controlled conditions and field trials, in collaboration with plant pathologist Pam Roberts and entomologist Phil Stansly, both at UFL, to examine the role of whitefly populations and insecticides on disease incidence.

Plant pathologist Scott Adkins and technician Carrie Vanderspool dissect a diseased watermelon plant to assess distribution of squash vein yellowing virus.

PEGGY GREB (D945-1)

In the spring of 2007, cucurbit leaf crumple virus (CuLCrV), another whitefly-transmitted virus, was found infecting watermelons in southwest Florida. The same team of scientists studying WVD made the discovery. CuLCrV had previously been reported in the western United States, and its recent appearance in Florida further highlights the importance of whitefly management.

Next, Figure Out What To Do

Plant pathologist Benny Bruton has worked with Adkins since the initial stages of WVD research, and plant pathologist Shaker Kousik joined the effort in November 2005. Bruton is at ARS's South Central Agricultural Research Laboratory in Lane, Oklahoma, and Kousik is at the U.S. Vegetable Laboratory in Charleston, South Carolina. Bruton isolated many bacteria and fungi and inoculated melons with the suspect microbes to see if they might be involved in the vine-decline syndrome.

"It was a long and painful process to identify which microbes may cause, or even contribute to, the disease—really a process of elimination," says Bruton. "Once Scott's team found the unusual virus and was able to demonstrate that it could cause essentially all the symptoms of vine decline—and that it was whitefly transmitted—it became essential to develop an integrated approach to manage or control the disease."

Together, Kousik, Bruton, and Adkins have been taking a nontraditional approach: grafting watermelon onto gourd rootstock. Bruton and other researchers have had excellent results in controlling fungal vine declines of watermelon, such as *Verticillium* wilt, caused by *Verticillium dahliae,* and *Fusarium* wilt, caused by *Fusarium oxysporum*. The researchers wanted to see whether grafted transplants would also be resistant to, or tolerant of, the new viral vine decline. They have been testing grafted watermelons in several farmers' fields in Florida, in field trials with UFL scientists, and in greenhouse trials in Fort Pierce.

Also, Kousik and Adkins have been screening watermelon germplasm for resistance to SqVYV in the greenhouse and field in Florida. They have identified several potential sources of resistance in wild-type watermelon. The germplasm was obtained from the ARS Plant Genetic Resources Conservation Unit at Griffin, Georgia. Kousik is also evaluating combinations of insecticides and silver plastic mulch to manage whitefly populations and thus WVD.

The Florida Watermelon Association and the National Watermelon Association have been very supportive of this collaborative research effort, greatly speeding up its success.—By **Alfredo Flores,** ARS.

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

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PEGGY GREB (D943-1)

Plant pathologists Scott Adkins (left) and Shaker Kousik study wild watermelon germplasm for resistance to squash vein yellowing virus.

A Trap for the Small Hive Beetle

Bees make the agricultural world go 'round—at least the fruits and nuts part of agriculture. Crops such as apples, pumpkins, almonds, and sunflowers all depend on honey bees to pollinate their flowers. In addition to their pollination contribution, bees produce more than 17 million pounds of honey each year in Florida alone. But in recent years, pests have been reducing honey bee numbers and threatening large sectors of agriculture.

One such pest, which has appeared in the United States in the last 10 years, is the small hive beetle *(Aetina tumida)*. In bee colonies already stressed by other pests or diseases, the beetles are able to evade guard bees and access the hive's pollen and other food resources.

Peter Teal, research leader of the Chemistry Research Unit at the Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, and his colleagues have developed a trap and an attractant to help beekeepers protect their bees from this pest, which has spread throughout the eastern portion of the United States.

When small hive beetles invade a beehive, they bring in a yeast that grows on the pollen. "As the yeast grows and ferments, it releases compounds that mimic honey bee alarm pheromones and are highly attractive to other beetles," says Teal. "This sets off a cascading effect. When the beetle population gets too high, the bees have no choice but to abandon the hive, leaving beekeepers without honey and their bee colonies."

In cooperation with several beekeepers, the team of scientists decided to use the small hive beetle's biology against it. They developed a trap that is baited with the small hive beetle yeast. The trap is installed below a hive and separated from it by sliding doors drilled with cone-shaped holes. Hive beetles can get through the holes and into the traps, but they can't get back out.

The trap could be a boon to the bee industry in Florida, which is a common overwintering destination for bees. A patent for the trap was filed in March 2005. "We think these traps will solve the problem for small-scale beekeepers, which make up 60 percent of the industry," Teal says. "They tend their hives daily and can clean their traps often."

For large-scale beekeepers, who maintain up to several thousand hives, Teal and his team plan to develop a new trap requiring less management.

Teal also hopes to devise a similar way to reduce populations of *Varroa* mites—another significant pest of honey bees. "If we can find out what makes these pests tick, we might be able to find out how to prevent them from causing further harm to this industry," says Teal.—By **Sharon Durham,** ARS.

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

JACK DYKINGA (K4716-3)

Honey bee on an apple blossom.

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Defending Against Two Cotton Pests—

Naturally

STEPHEN AUSMUS (D1002-11)

Entomologist Patricia Glynn Tillman (center), technician Kristie Graham (right), and student technician Brittany Giles evaluate a sorghum trap crop being used to control stink bugs in adjacent fields of peanuts and cotton.

Cotton growers used to be bedeviled by boll weevils. Now, thanks to a successful large-area eradication program, the weevils are no longer a problem in most U.S. cotton fields.

But stink bugs have filled the void boll weevils left in parts of the Southeast. Stink bug infestations cost Georgia farmers about 3 percent of their cotton in 2003.

Entomologist Patricia Glynn Tillman in ARS's Crop Protection and Management Research Unit at Tifton, Georgia, and entomologist Ted Cottrell in ARS's Fruit and Nut Research Laboratory at Byron, Georgia, are exploring use of trap crops in combination with pheromone traps to control two troublesome members of the family Pentatomidae: brown stink bugs *(Euschistus servus*) and southern green stink bugs *(Nezara viridula).* Trap crops are small plots specially planted to attract various pests away from cash crops or to concentrate the pests in a small area for more efficient disposal.

During 5 years of study, the researchers conducted on-farm tests to determine the usefulness of combining a sorghum trap crop with pheromone-baited capture traps to keep stink bugs out of cotton.

Peanut-cotton and corn-cotton farming configurations, or "farmscapes," are common in the Southeast. Stink bugs appear to prefer corn and peanuts but will move to adjacent cotton fields when their food supply runs low. However, the pests are ravenous for sorghum!

So, Tillman and colleagues planted sorghum in a strip along the entire length of a peanut-cotton interface. Pheromone-baited capture traps were placed about 45 to 50 feet apart in various rows. The researchers found that the *E. servus* population was significantly lower in cottonfields that had the two management strategies than in cottonfields without them.

In studies of *N. viridula* populations in a corn-cotton farmscape, the researchers planted a trap crop of sorghum at the interface of the two crops. The density of *N. viridula* was lower (0.12 bug per 6-foot row) in cottonfields with the sorghum trap crop than in cottonfields without it (1.16 bugs per 6-foot row).

"We proved that sorghum could also serve as a trap crop for *N. viridula* adults in a corn-cotton farmscape," says Tillman. "And by dispensing traps baited with the aggregation pheromone for *Euschistus* species, we were also able to capture *E. servus* in the field and control their populations in cotton.

"We got a two-part action," Tillman says. "The sorghum attracted *E. servus* and *N. viridula,* and the pheromone-baited traps captured the *Euschistus* as well as some *N. viridula."*

As an added benefit, the sorghum served as a refuge for stink bugs' natural insect enemies, such as the tachnid fly *Trichopoda pennipes,* further helping to protect the cotton plants.

"These encouraging results demonstrate that biologically intensive practices can be effective in controlling stink bugs and can assist farmers in providing quality crops to consumers," says Tillman.—By **Sharon Durham,** ARS.

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

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STEPHEN AUSMUS (D1005-2)

The brown stink bug, *Euschistus servus,* is about 11 mm long.

PEGGY GREB (D970-2)

Fruitful Studies in Puerto Rico

Lush climate and varied soils support research on tropical crops.

Scientists at the ARS germplasm repository in Mayagüez, Puerto Rico, carry out research to evaluate and develop integrated production systems for numerous tropical fruit crops and to conserve the germplasm of these crops.

The heat and humidity are no bother to Ricardo Goenaga as he walks from tree to 9-foot-tall tree in an experimental plot ARS maintains in Isabela, on Puerto Rico's northwest coast.

The plant physiologist picks a red, spiky, Ping-Pong-ball-sized fruit from one tree and uses his thumbs to peel it open and reveal bright, off-white flesh. He takes a bite. "A bit bitter," he says.

Goenaga samples another of the peculiar morsels on an adjacent tree. "Not quite right."

There's success at the next stop. On taking a taste, Goenaga's eyebrows rise, and he nods affirmatively. "Yes, here," he says. "This is some good rambutan."

He's right. The pulp inside this curious offering's soft skin—the reddish fruit resembles one of those squeeze toys covered by long, rubbery spikes—has the sweet taste of a pear.

Rambutan (ram-bu-TAHN), *Nephelium lappaceum,* is among the more fascinating examples of exotic tropical fruit studied at ARS's Tropical Agriculture Research Station (TARS), a versatile and unique research laboratory based in Mayagüez. "It quickly becomes a favorite to those who don't know it," says Goenaga. "Adults back off at first. But the kids love it! Their eyes open wide, and they say, 'What *is* this strange thing?'"

While rambutan and other fruits such as mamey sapote (mam-EY sa-PO-tey), lychee, longan, carambola, mangosteen, and sapodilla may not be typical stateside fare, they are often the center of attention at TARS. Much of the research there revolves around seeing these offerings on stateside shopping lists one day.

PEGGY GREB (D974-1)

Horticulturist Brian Irish (left) and plant physiologist Ricardo Goenaga inspect cacao pods. The Mayagüez repository maintains a genetically diverse collection of cacao, comprising almost 200 accessions.

An Increasing Demand

"Increases in health consciousness and ethnic diversity have greatly expanded the market for tropical fruit in the United States," says Goenaga, who is the station's research leader. "But there are major obstacles—such as pests, diseases, drought, and acidic soils—that keep growers from capitalizing on this. For example, unless irradiated, rambutan can't be imported into the United States because of concerns that it may introduce fruit flies.

"Our goal is to identify—through selection of superior clones and development of best crop-management practices—high-yielding versions of these crops that can meet these challenges," says Goenaga. "We want to help the tropical fruit industry expand its trade and to provide small farms and socially disadvantaged farmers with alternative high-value crops and effective management practices."

TARS scientists study large-scale cash crops as well as little-known exotic ones. And the station is one of three ARS repositories—keepers and guardians of genetic material known as "germplasm"—for tropical and subtropical plants.

"We safeguard cacao, banana, and plantain, as well as sapodilla, mamey sapote, Spanish lime, tropical and temperate bamboo, and species of *Annona* and *Garcinia*," says Goenaga.

The Fruit Fly Factor

He says that while some exotic fruits won't be exportable to the continental United States any time soon, there is a glimmer of hope for mamey sapote, *Pouteria sapota,* courtesy of work led by entomologist David Jenkins.

PEGGY GREB (D965-1)

Mamey sapote is one of many tropical fruits found in the ARS germplasm repository in Mayagüez, Puerto Rico.

This cantaloupe-sized brown fruit—it resembles a small coconut, while its sweet, refreshing flesh is reminiscent of almond-flavored ice cream—is a favorite niche product in the United States. "It's especially prized by the Cuban community but is also enjoyed by other ethnic groups," Jenkins says.

Import of mamey sapote from Puerto Rico has been restricted by concerns that it may host the West Indian fruit fly, which is not currently present in the continental United States.

Jenkins and colleagues recently found evidence that the probability of fruit fly infestation in mamey sapote is extremely low in Puerto Rico. "This is one step toward making this fruit eligible for export," says Jenkins.

His team recovered no adult fruit flies from more than 1,100 mature mamey sapote fruit collected throughout the year. "We also exposed the fruit to mature female fruit flies for 2 days," he says. "No eggs, larvae, or adults were recovered from any of the fruit." Experiments in rambutan are yielding the same results. In contrast, mangoes, identically exposed, yielded large numbers of fruit flies.

Jenkins cautions that experimental procedures following USDA Animal and Plant Health Inspection Service protocols must now be conducted to determine mamey sapote's final host status for this and other fruit flies.

An Ideal Study Site

Though they seem right at home, many exotic fruits studied at TARS come from lands far from Puerto Rico. The island's soils and climate help make it a valuable site for evaluating them. "Ten of the 12 soil orders recognized worldwide are

PEGGY GREB (D971-1)

Horticulturist Brian Irish (foreground) and technician Roberto Bravo harvest and weigh banana bunches from the germplasm collection.

PEGGY GREB (D963-1)

In a study of the fruit's potential as a host to fruit flies, entomologist David Jenkins inspects a fruit-fly trap on a carambola tree.

Technicians Elkin Vargas (foreground) and Nicolas Diaz harvest rambutan fruit from an experimental orchard.

PEGGY GREB (D958-1)

Rambutan fruit with edible pulp exposed.

PEGGY GREB (D959-1)

present here," says Goenaga. "This gives us the advantage of screening germplasm in various agro-environments within a short driving distance."

On a day-long journey, Goenaga drove the island's mountain roads to TARS experimental sites in Isabela, with its fine, well-drained soil, and in Corozal—southwest of San Juan—where the damp, clayey hills offer deep, strongly acidic, and poorly drained terrain. In Santa Isabel, on flood plains off the semiarid south-central coast, the soil is deep, well drained, and fertile.

The large-scale cash-crop research at TARS focuses on bananas and plantains (in the *Musa* genus), cacao, papaya, beans, and sorghum. "We introduce and evaluate new accessions of these crops and distribute disease-free plant genetic material from them," says Goenaga.

Horticulturist Brian Irish and Goenaga work to preserve and evaluate *Musa*. "These are among many tropical and subtropical crops whose germplasm resources have been reduced by human activity, pests, diseases, and weather-related causes," says Irish.

Musa and Cacao

While high genetic diversity exists in *Musa*'s centers of origin in Southeast Asia, Irish says that uniformity requirements for dessert bananas have diminished diversity in cultivated bananas and led to a reliance on Cavendish types.

Though extremely popular for their high yield and good taste, Cavendish varieties are very susceptible to important insects and pathogens. "We're currently evaluating *Musa* germplasm accessions in our collection as potential alternatives to Cavendish types," says Irish.

In all, TARS holds 29 accessions of plantain and 92 accessions of banana, representing popularly grown cultivars, insect- and disease-resistant cultivars, and other previously uncharacterized varieties and plant introductions.

Irish also serves as curator for cacao, managing a collection that was reestablished in 2000.

No cacao is produced commercially in Puerto Rico. "But it is at risk from diseases that thrive in the warm, humid conditions of its native lands and that exist here," says Irish. "That plus our variety of soil types and ecological zones make the island ideal for evaluating cacao germplasm."

"There's no doubt that we are breaking a lot of ground, both on exotic fruit and larger-scale tropical and subtropical crops," says Goenaga. "Some of these exotic fruits are now close to being ready for the export market.

"But the future here at TARS is in the germplasm," he adds. "We need as much genetic diversity in our collections as possible so that we can evaluate and identify materials with superior horticultural traits and thus ensure success and sustained production for the emerging tropical fruit industry."—By **Luis Pons,** formerly with ARS.

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

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An **Exotic Fruits** Sampler

Here are some details about other fruits being studied at ARS's Tropical Agriculture Research Station, Mayagüez, Puerto Rico.

Mangosteen, *Garcinia mangostana.* This "Queen of Fruits," as it's known in its native East Indies, has a red/purple, edible rind and fragrant, sweet, and creamy flesh that tastes like citrus and peach. It's not related to mango.
Scientific challenges: Mangosteen's tropical evergreen trees take 8 to 15 years to start bearing fruit, a characteristic that worries potential growers in storm-prone areas. Scientists are trying to accelerate its growth or make its juvenile stage shorter.

Lychee, *Litchi chinensis.* This oval fruit is a little more than an inch in diameter and comes from China. It has a hard, scaly, reddish and inedible cover, but sweet, whitish, grapelike edible flesh that surrounds a single large seed.
Scientific challenges: Only a few of the approximately 70 known varieties of lychee have been studied or evaluated. Selection of superior varieties with high yield potential is essential for industry expansion.

Longan, *Dimocarpus longan.* This relative of lychee has small, pulpy fruit produced by a Southeast Asian evergreen tree nicknamed "dragon eye" because its fruit has black seed that shows through translucent flesh, resembling an eyeball. Its thin, brown shell is inedible.
Scientific challenges: Major problems associated with longan production are overcropping and alternate bearing—the tendency to bear a large crop of fruit one year followed by little or no fruit the next year. Best management practices for high-yielding cultivars are needed.

Carambola, *Averrhoa carambola.* Known as "starfruit," this offering is also of Southeast Asian origin. It's a five-angled, green-to-yellow tropical fruit with a star-shaped cross-section and edible skin. Its tart-sweet taste resembles that of apples or grapes. A good source of vitamin C and antioxidants, carambola is commercially grown in Florida and Hawaii.
Scientific challenges: Selection of rootstocks that adapt well to alkaline and acid soils in the Tropics and Subtropics is needed.

Sapodilla, *Manilkara zapota.* This round to egg-shaped fruit is 2 to 4 inches in diameter, with rough brown skin. The flesh—it varies from yellow to reddish-brown—can be smooth or grainy. It has an extremely sweet flavor.
Scientific challenges: Selection of rootstocks promoting tree dwarfing and development of resistance to various root weevils are of critical importance.

PEGGY GREB (D972-1)

Mangosteen.

PEGGY GREB (K10889-1)

Lychee.

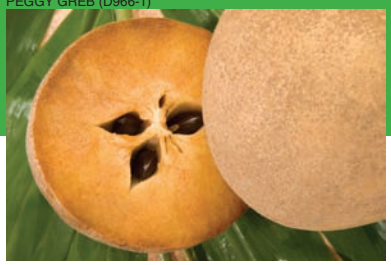
SCOTT BAUER (K7891-1)

Longan.

PEGGY GREB (D964-1)

Carambola.

PEGGY GREB (D966-1)



Sapodilla.

Diamond Planting Design and Planter for Peanut Crops

A variety of machinery and techniques is required to plant, cultivate, and harvest the wide range of U.S. agricultural commodities.

Over the years, ARS has researched many innovations in equipment and methods. For example, adapting equipment to plant runner-type peanuts in a diamond formation has been found to increase yield and improve disease management over the single-row planting method. ARS agronomists Russell Nuti and Ron Sorensen at the National Peanut Research Laboratory (NPRL) in Dawson, Georgia, are continuing this research, which was first developed by former NPRL agricultural engineer Don Sternitzke.

In a diamond formation, each 3-foot-wide planting bed has four equidistant rows, with six seeds planted per foot. Spacing plants in this uniform, staggered manner has been found to reduce plant-to-plant competition and achieve canopy closure sooner, helping to keep the soil cool and moist.

Now, a new 3-year research study is being conducted with Naveen Puppala and Sangu Angadi of New Mexico State University using Valencia, a more erect-growing peanut type.

Valencia's upright growth habit may make it more amenable to the diamond planting arrangement than vinelike varieties grown in Georgia. "Valencias don't achieve row closure like runners do, especially when planted in single rows," says Nuti. "Another benefit of the diamond planting configuration is that the crop has a better chance to outcompete weeds, thus reducing early competition for water, nutrients, and light."

In first-year data collected, it appears that several populations of diamond planting are equal in yield and profit to a twin-row configuration and that both diamond and twin-row outproduce the conventional single-row.

"It is apparent that both twin-row and diamond patterns increased yield and profit," says Nuti. "But we still need to know more about how planting patterns affect growth and fruiting."—By **Sharon Durham,** ARS.

This research is part of Crop Production (#305) and Water Resource Management (#201), two ARS national programs described on the World Wide Web at www.nps.ars.usda.gov.

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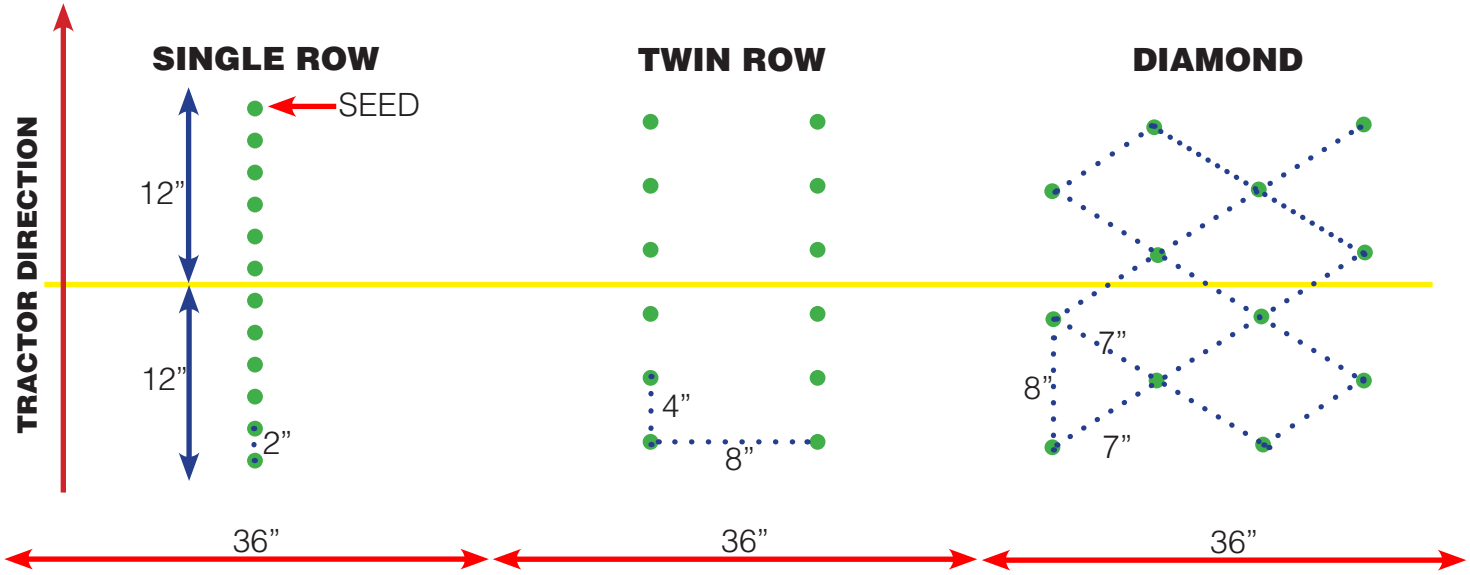

STEPHEN AUSMUS (D1068-1)

Testing Biocontrols for Peach Pests

Lesser peachtree borer, *Synanthedon pictipes*.

STEPHEN AUSMUS (D1066-19)

At the Southeastern Fruit and Tree Nut Research Laboratory in Byron, Georgia, entomologists Ted Cottrell (left) and David Shapiro-Ilan examine damage caused by the lesser peachtree borer.

Peaches are a significant part of the South's fresh-produce industry. But since several insect pests pose serious threats to southern peach orchards, growers must often resort to costly pesticides to protect their fruit.

At ARS's Southeastern Fruit and Tree Nut Research Laboratory in Byron, Georgia, entomologists David Shapiro-Ilan and Ted Cottrell are seeking environmentally friendly alternatives. In cooperation with Russ Mizell at the University of Florida and Dan Horton at the University of Georgia, the ARS researchers are evaluating two tiny, soil-dwelling nematodes as possible biological controls.

Plum curculio, *Conotrachelus nenuphar,* is a tiny, snout-nosed beetle and major pest of stone fruits, including peaches. Adult insects damage peaches through feeding on and laying eggs in the fruit, resulting in characteristic crescent-shaped wounds on the fruit. Infested fruits often fall prematurely and are unmarketable. Later, mature larvae emerge from the fruit and develop in the soil, completing the insect's life cycle.

Shapiro-Ilan and Cottrell found that soil applications of the nematode *Steinernema riobrave* can suppress plum curculio larvae by 78 to 100 percent. "Nonfeeding infective juvenile nematodes seek out larval hosts," says Shapiro-Ilan. "When one finds a larva, it penetrates its body. Once inside, it releases a bacterium that multiplies rapidly and kills the host. The nematode then reproduces while feeding on the bacteria and insect tissues."

Curbing Airborne Marauders

Stone fruits are also plagued by clear-winged moths such as the peachtree borer, *Synanthedon exitiosa,* and the lesser peachtree borer, *S. pictipes*. Another beneficial nematode, *St. carpocapsae,* is virulent to both closely related hosts.

With peachtree borers, field applications of the *St. carpocapsae* nematode achieved high levels of borer control. That's in part because the nematodes were protected

from desiccation (drying) and ultraviolet damage by their subsoil environment.

"We found that a single application of *St. carpocapsae* provided 88-percent suppression when applied to mature peachtree borer infestations in springtime," says Cottrell. "And in a recent field trial, three applications of *St. carpocapsae* during the peachtree borer's fall egg-laying season completely suppressed all damage."

Though they knew from laboratory studies that the lesser peachtree borer is also highly susceptible to *St. carpocapsae,* Shapiro-Ilan and Cottrell realized that its control would be more difficult. That's because lesser peachtree borers attack trees aboveground, feeding in galleries within trunks and limbs.

"Initially, we just applied nematodes to lesser peachtree borer wounds, and—as expected—the nematodes failed to cause any significant suppression," says Shapiro-Ilan. But the researchers then found that when nematodes were given adequate protection, they provided a high level of borer control.

To achieve that protection, they applied *St. carpocapsae* nematodes to tree wounds and then covered the wounds with moisture-holding bandages. "In our first trial," says Cottrell, "we saw 100-percent borer suppression just 5 days after treatment."

This suggests that further research will help peach growers make significant headway against these troublesome pests.—By **Sharon Durham,** ARS.

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

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When protected, the nematodes provided a high level of borer control.

STEPHEN AUSMUS (D1067-5)

Technician Rebekah Long sprays beneficial nematodes onto a tree wound to control lesser peachtree borer. Technician Chris Paulsen prepares to apply a bandage to protect the nematodes and prolong their survival.

TifQuik for Faster Forage

Forage growers would naturally like to get the jump on weeds and extend their forage production season. So Agricultural Research Service geneticist Bill Anderson of the Crop Genetics and Breeding Research Unit in Tifton, Georgia, and his colleagues have developed a new bahiagrass *(Panicum notatum)* cultivar that may help them do just that.

Released by the U.S. Department of Agriculture (USDA) and the University of Georgia (UGA) TifQuik has great promise as a forage grass in the Southeast. Currently, Tifton 9 bahiagrass, another USDA/UGA variety, developed by the late Glenn Burton, an ARS Hall of Fame member, is widely grown for forage, with good results. But the TifQuik cultivar is even better.

"TifQuik was developed to have reduced hard seed and thus faster germination and field establishment than Tifton 9," says Anderson. "These features mean that a TifQuik-seeded pasture will be covered earlier, and grazing or hay removal can be performed sooner—with higher initial yields."

The bahiagrass cultivars now grown have a considerable amount of hard seed and thus require 2-3 weeks to establish a full stand. During this time, weeds may infest the pasture, and moisture for forage seed germination may be restricted.

In developing TifQuik, the sole criterion for selection of plants was fast germination. It took 4 years to achieve the desired qualities. Former ARS agronomist Roger Gates and retired geneticist Wayne Hanna performed the four selection cycles, beginning with Tifton 9. During each cycle, enough seed was planted from the previous one to obtain 1,000 seedlings that germinated within the first week. Seedlings were transplanted to clay pots in the greenhouse and then to a fumigated field to establish a nursery. Plants were allowed to cross-pollinate, seed was hand-harvested, and that seed was then used to start the final cycle, the following spring, in a greenhouse. The four cycles were completed in 2002, and the seed from 2002 was used to establish greenhouse germination tests and a replicated field test and to begin seed increase.

In the greenhouse studies, germination of TifQuik averaged five times more than Tifton 9 after 6 days and three times more after 8 days. In the field studies, TifQuik emerged about 75 percent faster after 1 week than Tifton 9 and Pensacola, another commonly used forage bahiagrass. After 4 weeks, TifQuik plants were taller than both Tifton 9 and Pensacola. Dry-matter yields of TifQuik were two times higher than Tifton 9 and four times higher than Pensacola for the first clipping, which was done 2 months after planting.

"TifQuik will be particularly valuable to growers who wish to include bahiagrass in a sod-based rotation system with row crops such as peanut and cotton in the southeastern United States," says Anderson. "Bahiagrass has been shown to reduce nematode and disease problems in subsequent crops, and it should provide many forage growers with another tool to make their operations more efficient and, hopefully, more profitable."—By **Sharon Durham,** ARS.

This research is part of Rangeland, Pasture, and Forages, an ARS national program (#205) described on the World Wide Web at www.nps.ars.usda.gov.

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STEPHEN AUSMUS (D1074-6)

In a replicated plot outside Tifton, Georgia, technician Freddy Cheek (left) and geneticist Bill Anderson harvest grasses to measure yields, dry matter content, and quality.

STEPHEN AUSMUS (D1076-2)

A distinguishing trait of bahiagrass is its V-shaped seed head (or inflorescence).

Perennial Peanut for Quality Pasturage and Hay

No other perennial warm-weather legume adapted to the Gulf Coast comes close to the rhizoma perennial peanut *(Arachis glabrata)*. It's often called "the alfalfa of the South" because its protein and mineral content are very similar to alfalfa's. But as a long-lived perennial in the region, *A. glabrata* is less costly to grow than alfalfa. Its recognized quality, persistence, and broad uses are making it a good forage crop in the lower South.

Rhizoma perennial peanut has become the premium forage for the Gulf Coast due to more than 50 years of collaborative work among several state and federal cooperators, says Mimi Williams, former forage agronomist at the USDA-ARS Subtropical Agricultural Research Station (STARS) in Brooksville, Florida, and now with USDA's Natural Resources Conservation Service (NRCS) in Gainesville, Florida. In addition to STARS, the NRCS Brooksville Plant Materials Center and the University of Florida's Institute of Food and Agriculture Sciences (IFAS) worked on this long-term effort.

Williams says that interest in *A. glabrata* began when a collection of accessions from South America was introduced to Florida in the 1930s. This initial work resulted in the informal release of selections Arb and Arblick in the 1960s, but both had very limited use because of slow establishment and low productivity. That changed in the 1980s, with formal release of the cultivars Florigraze and Arbrook, which produce much higher amounts of forage than the earlier releases.

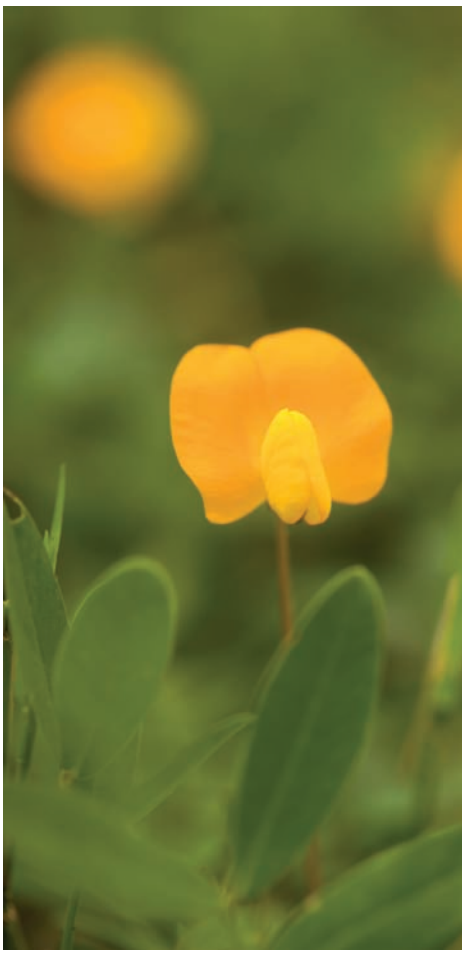
Extensive research conducted by Williams and coworkers at Brooksville in the 1980s and 1990s demonstrated the nutritional value of *A. glabrata* to livestock and is widely responsible for its current popularity as a hay crop.

Horse, goat, and dairy producers in the region imported more than $100 million worth of hay per year before the perennial peanut became available.

PEGGY GREB (D1029-1)

Research leader Sam Coleman harvests perennial peanut *(Arachis glabrata)* for yield and quality analysis.

PEGGY GREB (D1030-1)



Perennial peanut *(Arachis glabrata)* blossom. The plant produces blossoms even though it produces very little viable seed.

Adapted to upland soils of the lower Coastal Plain, it's being used throughout much of the eastern Gulf Coast region, with an estimated 25,000 acres planted in Florida and southern Georgia. Much of it is being grown on row-crop ground that previously had very marginal returns. Now, *A. glabrata's* net profit exceeds $1,000 annually per hectare, with current demand for hay exceeding production. Current sales—mainly as hay, but also as planting material and ornamentals—exceed $7 million.

"It's a win-win situation for everyone," says Sam Coleman, research leader at STARS. "Financially, it makes sense for hay producers to grow perennial peanut, and as long as there are cattle and horses in Florida, there'll always be a demand," adds Coleman.

Researchers are now seeking ways to make the perennial peanut more economical to grow for hay or forage in wetter soils or in more northern areas of the region. Traditional breeding methods aren't practical because the plant produces very little seed, so new plant material has been sought from its native range in South America.

While at STARS in the early 2000s, Williams—working with others at ARS's Plant Introduction Station in Griffin, Georgia—led two expeditions to Paraguay to find germplasm for expanding the range of perennial peanut. They brought back 85 accessions of wild and domesticated plants for testing. Those plants serve as the basis for the current *A. glabrata* research by Coleman at STARS; Andrea Maas, a plant geneticist at ARS's Crop Genetics and Breeding Research Unit in Tifton, Georgia; and researchers from NRCS and IFAS.—By **Alfredo Flores,** ARS.

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

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PEGGY GREB (D1031-2)

Romosinuano heifers grazing a pasture mixture of perennial peanut *(Arachis glabrata)* and bahiagrass *(Paspalum notatum).*

Managing Beef Cattle To Protect Lakes and Rivers

PEGGY GREB (D1025-1)

Soil scientist Gilbert Sigua uses a probe to measure levels of salinity, dissolved oxygen, conductivity, and temperature in Spring Lake, in Brooksville, Florida. The lake is located near forage-based cow-calf operations.

Beef cattle browse more than 11 million acres of grazinglands in the State of Florida. In fact, Florida is 11th among U.S. beef-producing states, and 4th among those with herds of more than 500 brood cows. Florida producers run 4 of the nation's 15 largest ranches, the largest of which grazes over 35,000 brood cows on more than 300,000 acres.

Such large herds naturally generate large quantities of manure and other waste. Because of this, forage-based livestock systems have been blamed as a major cause of deteriorating water quality in Florida and other cattle-producing states. Particularly problematic, over time, has been phosphorus runoff from both manure and the fertilizers applied to enhance forage production.

Despite widespread concern, however, very limited data has been available to measure nutrient losses to adjacent bodies of water from pastures managed for grazing and hay production.

That's where the Beef Cattle Research Unit—part of ARS's Subtropical Agricultural Research Station (STARS)—in Brooksville, Florida, comes in. There, in west-central Florida, soil scientist Gilbert C. Sigua and colleagues examined changes in soil fertility of bahiagrass-based beef cattle pastures from 1988 to 2002. The pastures were managed for grazing in spring and haying in late summer. Soil analysis has shown declining nutrient levels, especially of phosphorus.

The three major pasture units had a combined total area of about 3,800 acres, with 3,200 acres in permanent pasture. Cattle used for nutritional, reproductive, and genetic research on the station include about 500 head of breeding females with a total inventory of about 1,000 head of cows, bulls, and calves.

"Overall," says Sigua, "we've found no spatial or temporal buildup of soil phosphorus or other crop nutrients—despite the annual application of fertilizers and daily in-field loading of animal waste."

Everything Goes Together

How pasture management and hydrology interact to affect nutrient dynamics and water quality has become an issue of increasing importance to environmentalists, ranchers, and public officials. So, since phosphorus has been found to be the culprit in nutrient pollution, or eutrophication, in many Florida aquatic systems, the STARS scientists and collaborators have launched several studies on reducing phosphorus runoff.

Long-term monitoring of changes in soil nutrients, especially phosphorus, helps the STARS soil scientists to predict soil chemical buildup or physical deterioration that could occur under continuous forage-livestock cultivation and to adopt measures to prevent them from happening.

TSI—for Total Water Quality

Using what's called the "trophic state index" (TSI), Sigua and colleagues followed trends in the quality of water in three lakes near Brooksville from 1993 to 2002. TSI is an indicator of the overall condition of a body of water, including its biological, chemical, and physical characteristics. According to Florida Water Quality Standards, a TSI score between 0 and 59 is considered "good"; 60 to 69 is "fair"; and 70 to 100 is "poor."

The lakes tested are either next to beef cattle pastures or within a 5- to 10-mile radius of STARS. Measures of water chemistry made during the 1990s in Lake Lindsey proved similar to what had been found 30 years before. Spring Lake samples showed clear, medium-hard water

with a low concentration of total nitrogen and total phosphorus. Water in Bystre Lake was characterized as moderately colored and medium-hard.

The TSI scores for all 3 lakes were in the "good" range: 35 for Lake Lindsey, 30 for Spring Lake, and 46 for Bystre Lake.

Those findings indicate that current fertilization recommendations for bahiagrass-based pastures in central Florida offer little potential for harming the environment. They suggest that livestock operations might not be major contributors to excess loads of nutrients—especially phosphorus—in nearby surface waters, as long as the operations are properly managed. If the phosphorus is not showing up in the local system, it may be moving farther off site via groundwater flow.

High-Quality Forage for Hay and Grazing

Long-term study results show that the current recommendation for phosphorus may, in fact, be too low to adequately maintain growth of rhizoma peanut, *Arachis glabrata.* This perennial forage legume is well adapted to the warm, humid climate of central Florida, where it's grown alongside bahiagrass.

The high nutritional value of rhizoma peanut makes it an excellent feed for both ruminant and nonruminant animals. Periodic application of additional phosphorus and other micronutrients may be necessary to meet the forage peanut's agronomic needs and to offset the nutrients lost because of animal production.

For the next 5 years, Sigua and other collaborators will be integrating the environment, plants, and animal genetic resources into a sustainable beef cattle agroecosystem for the subtropical United States. They will continue their research endeavors with the goal of optimizing forage-based cow-calf operations both to improve pasture sustainability and to protect water quality.—By **Alfredo Flores,** ARS.

PEGGY GREB (D1028-1)

Technician Kirstin Foulks prepares groundwater samples for analysis. Water samples were taken from a forage-based pasture in a cow-calf operation.

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

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PEGGY GREB (D1026-1)

Gilbert Sigua and Kirstin Foulks take groundwater samples from a forage-based pasture in a cow-calf operation at the Subtropical Agricultural Research Station at Brooksville, Florida.

MARK FARNHAM (D1083-1)

Field plots at Charleston, which contain grow-outs of collard samples collected from Carolina seed-savers, illustrate the variation among samples for traits like leaf color, shape, and size.

A Collection of Carolina Collards

Around New Year's Day, there's not much green on the coastal plains of North or South Carolina, except for neat rows of collards (*Brassica oleracea).* Different varieties of this leafy vegetable are nurtured by gardeners who sow their collard crops from heirloom seeds passed down through generations.

These fields provide garden greens through the late winter—and they are a treasure trove of diverse collard genetic material, or germplasm. To ensure that this valuable resource doesn't vanish, Mark W. Farnham has begun collecting heirloom collard seeds for preservation in the USDA National Plant Germplasm Collection (NPGC).

Farnham conducts plant genetic research for the Agricultural Research Service (ARS) in Charleston, South Carolina. In 1996, while studying just a few of these old collard varieties—also called "landraces"—he found distinct collard genotypes worthy of collection and preservation.

"Though a lot of these collard varieties are being perpetuated to this day, the different landraces still grown in the region are now in the hands of an aging population," Farnham says. He realized that the caretakers who cultivated these plants could provide no guarantees for the long-term preservation of the heirloom landraces.

In 2003, the NPGC Plant Exchange Office provided funding for Farnham and his colleagues—entomologist Powell Smith of Clemson University and geographers John T. Morgan and Edward Davis of Emory and Henry College—to search for collard seeds in North and South Carolina.

A Homegrown Favorite Goes Commercial

Collard—a cole crop related to broccoli, cabbage, and cauliflower—has always been a local staple in the South. But its commercial cultivation expanded dramatically in the 20th century, and is now dominated by a few hybrid varieties.

Collard production in the United States was valued at some $36 million in 2002, when Georgia led national production with almost 6,000 harvested acres. That same year, North and South Carolina harvested more than 2,000 acres each.

Commercial collard crops are not widely grown during hot and humid summer months because they are especially vulnerable to diseases like *Fusarium* fungus and a variety of insect pests. There have been other downsides as well.

"The genetic erosion of the collard germplasm pool has been severe in recent years because commercial collard hybrids have been adopted by both large-scale producers and home gardeners,"

Farnham notes. But plots of heirloom collards can still be found throughout this region.

These collards—often sold at farmers' markets and roadside stands—are planted in August, and foot-long leaves are harvested from November to the end of February. The plants then flower and produce seeds that are gathered up and stored until the next round of planting.

These crops may provide more than just local color. They could contain genes useful for improving commercial varieties of collard—and varieties of other cole crops as well. In his previous studies, Farnham found indications that these collard landraces carry some genetic resistance to *Fusarium*.

Searching for Seeds

For several years, Farnham and his associates traveled throughout the Carolina winters on scavenger hunts for seeds. If it was early in the season, they looked for patches of green. In March, they began scouting for bright-yellow collard blossoms, for if the plant was in flower, it signaled that seeds were being kept by the gardener.

When they found a likely field, they stopped and talked to the gardener to find out if the collards were a commercial variety or a landrace with a more limited distribution. If the plant turned out to be an heirloom variety, they asked the owner if they could collect some of its seeds.

"In general, nearly all the seed savers were happy to discuss the collards they were growing," Farnham says. "Usually, after talking for about an hour or so, they'd be more than willing to let us have some of their seeds." In this way, the team collected 87 collard seed samples, and sometimes obtained more than one landrace from a single saver.

These visits reinforced Farnham's fears that unique collard landraces might soon disappear. While the youngest gardener they met was 48, the oldest was almost 90, and most of them were at least 70 years old. There was little evidence that the older gardeners had younger family members or friends who would continue to plant the heirloom varieties in the years to come.

Farnham says, "Many of the places we visited probably won't have collard gardens in 10 years. I think we successfully saved some unique collard germplasm that was in danger of being lost very soon." The samples collected by the team are now part of the ARS collection of vegetable *Brassicas* at Geneva, New York, where scientists maintain facilities for the preservation of plant germplasm.

In his lab, Farnham has grown out plants from some of the collected seeds, which have yielded varieties with distinct leaf shapes, colors, and sizes. He believes these differences indicate that the collected seeds contain a rich and diverse germplasm in need of further definition and study.

More varied and sturdier collard cultivars will be good news for producers and consumers. In the meantime, Farnham is pleased with the results of his fieldwork. "Plant scientists are always excited by new plant varieties and unexpected genetic traits," he says. "It's been great to find diversity like this right in our own back yard."—By **Ann Perry,** ARS.

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

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Various Shades, Shapes, and Sizes

MARK FARNHAM (D1080-1)

A sampling of leaves from different Carolina collard landraces clearly shows leaf variation among them.

A Boost for Your Bones

Like other greens that are going gourmet, collards have a culinary following that extends far beyond their regional roots. That appreciation comes with benefits: In addition to vitamin A, USDA nutritionists have determined that collard leaves are loaded with an astonishing amount of bone-bolstering vitamin K.

Tracing Florida Mangoes' Family Tree

MIKE WINTERSTEIN (D1098-1)

At the ARS Subtropical Horticulture Research Station in Miami, Florida, geneticist Raymond Schnell evaluates early flowering in a mango seedling selection.

A highly esteemed traditional crop in India and Southeast Asia for centuries, mangoes have also become well established in tropical regions of Central and South America over the past 500 years. In the United States, mangoes are grown in Florida and Hawaii, as well as in Puerto Rico.

Introduction of mangoes into Florida and later development of a unique Florida group of mangoes have been thoroughly reviewed by ARS Subtropical Horticulture Research Station (SHRS) geneticist Ray Schnell in Miami over the past dozen years. In 1980, SHRS was formally named a clonal repository within the National Plant Germplasm System (NPGS) with primary responsibility for collecting and preserving mango and other subtropical crop species.

Mangoes belong to the genus *Mangifera,* which comprises about 30 species of tropical fruiting trees in the flowering plant family Anacardiaceae. The mango tree is referred to as *Mangifera indica*. While earliest plantings of mango germplasm at SHRS occurred in the 1920s, the first mango introductions to Florida date back to around 1880.

WILHELMINA WASIK (D1099-1)

Fruit of the Florida cultivar Tommy Atkins is just one of several hybrids that produce dependably over a range of environmental conditions.

Historically, mango has been highly revered in southern Asia, and it's been referred to as "the king of fruits." Among Hindus, its leaves are ritually used for floral decorations in religious ceremonies and marriages. Today it is cultivated in tropical and warmer subtropical climates in Asia, Africa, Australia, and the Americas. With more than 1,000 known cultivars, it's been said to be the most commonly eaten fresh fruit worldwide. Ripe mango is best known for its very sweet and unique taste, and its high water content makes it refreshing to eat.

One Shoot or Two?

Mango cultivars are classified based on the type of embryo that develops from the seed. Monoembryonic cultivars produce a single shoot, while polyembryonic types germinate multiple shoots. The early mango introductions to Florida were mostly from the West Indies and India. Cultivars from the West Indies flowered and set fruit well under Florida conditions but had a poor flavor. For instance, one of the most widely grown early West Indies introductions was nicknamed "Turpentine" because of its flavor; there are trace amounts of turpentine found in some rare varieties.

On the other hand, the early Indian mango cultivars were fine-flavored, but they flowered and set fruit poorly under south Florida conditions. So, through hybridization, cultivars were developed that embody desirable traits of Indian cultivars (mainly monoembryonic) and of Southeast Asian cultivars (mainly polyembryonic) and are suitable for production under Florida's subtropical conditions.

Charting Mangoes' Diversity

To efficiently develop improved mango cultivars, it is first important to understand genetic relationships among current Florida cultivars as well as their relationships to both Indian and Southeast Asian races. Schnell has been working with SHRS

colleagues—geneticists Steve Brown, Cecile Olano, David Kuhn, and Alan Meerow—to use microsatellite markers to evaluate the genetic diversity in the large collections of mangoes maintained at SHRS and at the Fairchild Tropical Botanic Garden, also in Miami. This will help identify the genes involved in mangoes' wide adaptation.

Leaf material used in this study, maintained at the SHRS germplasm repository, was broadly categorized into groups by geographic origin: Florida, India, Hawaii, Central America, South America, Africa, Israel, and the Pacific. Plants originating from Cuba, Puerto Rico, Haiti, Jamaica, Trinidad, and the West Indies were considered West Indian. The Southeast Asian group included plant material from Borneo, Burma, Indonesia, Philippines, Vietnam, Australia, Cambodia, Laos, and Thailand.

Closer to India

DNA extraction and analysis performed on the leaf tissue led to findings suggesting that Florida mango cultivar types are more closely related to Indian types than to Southeast Asian types. Interestingly, the Florida types were not found to be genetically more diverse than either of the originating parental groups.

But the Florida mangoes are unique, and a subset of them has proven to have an unusually high level of production stability and environmental adaptability. Among these productive, adaptable mangoes are Keitt, Tommy Atkins, Haden, Parvin, and Irwin, all of which produce dependably over a range of environmental conditions.

There was a marked difference that clearly separated *M. indica* populations—so much so that it separated Southeast Asian cultivars from all others. There was a close relationship between the Florida, Hawaii, and Israeli clusters—which was anticipated by the SHRS scientists, because much germplasm has been exchanged between plant breeders in the three areas.

WILHELMINA WASIK (D1100-1)

The Florida cultivar Keitt produces large fruit that tends to be pale green to pink and more of an elongated shape.

WILHELMINA WASIK (D1101-1)

Fruit of the Florida cultivar Haden, a monoembryonic mango whose characteristics include fine flavor, bright colors—such as red and orange—and a round shape. Haden is in the pedigree of most of the Florida mango cultivars.

"Understanding this valuable genetic architecture—how it arose, its mode of inheritance, and which mangoes have the highest rate of production and adaptability—will be of the utmost importance," said Schnell. "It'll be important both for future mango breeding efforts and for commercial production of mango, not only in Florida, but anywhere in the world with a similar climate."—By **Alfredo Flores,** ARS.

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

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STEPHEN AUSMUS (D1023-1)

Chillin' Chickens

Which Method Works Best?

After chicken carcasses have been immersion chilled or air chilled, food technologist Doug Smith removes broiler breast fillets while food technologist Julie Northcutt measures and weighs the fillets before they are processed with traditional marination and cooking techniques.

Chicken processing is big business with almost 9 billion broiler chickens being produced in the United States last year. Processing birds efficiently and economically is the name of the game. And researching ways to convert poultry into food that is safe for human consumption is what Agricultural Research Service food scientists strive to achieve.

Quality and safety of poultry products for the U.S. consumer must be ensured. At ARS's Richard B. Russell Research Center, in Athens, Georgia, two ARS food technologists have examined the chilling stage of poultry processing to determine the best method for meat quality, food safety, and water management. Julie Northcutt is in the Poultry Processing and Swine Physiology Research Unit, and Doug Smith is in the Quality and Safety Assessment Research Unit.

More Than One Way To Chill Out

"While immersion chilling is still the predominant method used in the United States, seven poultry-processing plants have recently switched to air chilling, and several others have made arrangements to install air-chilling equipment in the near future," says Northcutt. This method may make significant inroads in processing in the United States and open new product markets, particularly in Europe.

It's important that carcass temperatures are quickly lowered after slaughter to prevent bacterial growth. The industry standard is to bring carcasses to 40°F or less within 4 to 8 hours (depending on carcass weight) after slaughter to inhibit growth of pathogens and spoilage microorganisms. Pathogens are those bacteria that cause foodborne illness when consumed.

"Cooling of poultry is typically accomplished by one of three methods—immersion chilling, dry-air chilling, or evaporative air chilling," says Northcutt. "In immersion chilling, carcasses are submerged in tanks of cold water or an ice and water mix. Dry-air chilling is achieved by blasting carcasses with cold air. Evaporative air chilling cools poultry down by a combination of cold-air blasts and water misting."

Since, air- and immersion-chilling systems are now being used commercially, Northcutt and Smith worked with University of Georgia graduate student Roger Huezo to compare the effects of air chilling and immersion chilling on the microbiological profiles of broiler carcasses and meat quality.

Northcutt, Smith, and Huezo found no significant difference in bacterial pathogen levels between the two chilling methods. "Each of the chilling methods reduced bacteria populations to similar levels," says Northcutt, "so once we discovered the similarities in carcass microbiology, we focused on water management and meat quality."

Chewy or Tender?

During commercial processing, whole carcasses are aged under refrigerated conditions to allow the muscle fibers to relax and become tender. After aging for a few hours, the carcasses may be cut into parts or deboned.

Northcutt and colleagues tested the most popular part of the chicken: breast fillets. They compared tenderness of fillets removed from carcasses immediately after chilling (0 hours aging) to fillets aged on carcasses for 150 minutes or 24 hours after chilling. For air- and immersion-chilling methods, all breast fillets were considered tender or very tender after 24 hours of aging, but shorter aging times caused variations in tenderness.

According to Smith, shorter aging times are of interest to the industry because plants have limited space to store carcasses after chilling, and the additional holding time is costly.

In the tests, immersion-chilled and air-chilled fillets were deboned immediately after chilling or after 150 minutes. The researchers found that 70 percent of the immersion-chilled fillets were slightly tough to tough, and 30 percent were tender to very tender. Of the air-chilled fillets, 44 percent were slightly tough to tough, and 56 percent were tender to very tender.

"In addition to improving meat quality, air chilling provided higher cooked-meat yields than immersion chilling. Color and texture of skinless breast fillets were similar for both chilling methods," says Northcutt. The team believes that the lower cooked yield of the immersion-chilled fillets was the result of high moisture absorption during chilling, which was later cooked out of the product.

The issue of aging only relates to poultry that is further processed. "Processors selling whole carcasses may not have a reason to make a switch to air chilling based on meat quality," says Northcutt. "Air chilling may, however, be a suitable alternative for deboning and other processing operations."

Water, Water Everywhere—NOT!

The two principal poultry chilling methods vary markedly in their water use. According to recent surveys, it takes an average of 7 gallons of water to process each bird. Immersion chilling requires almost 3/4 of a gallon of water per bird to fill the chill tank at each shift startup and another half gallon of overflow—about 60,000 gallons depending on the length of the chiller.

JULIE NORTHCUTT (D1036-1)

Simulated immersion chilling using a technique of individually bagging broiler carcasses. The bagging prevents bacterial cross-contamination from one carcass to another.

The southeastern part of the United States is struggling to meet the water needs of its residents, and water costs are at a premium. "In 2005, some poultry processing plants in the South had to cut back on the number of birds they processed because water was not available. The drought has encouraged the privatization of water, with new companies being developed just to sell one of our most precious natural resources," says Northcutt.

William Merka, former University of Georgia professor and poultry extension scientist, says water savings may be advantageous to processors. "Processors pay at least $4 for every 1,000 gallons for water and sewer cost," he says. "If they can save even half a cent per bird with water conservation, that would save about $1,250 per day or $325,000 annually. But cutting back on water use is about more than just economics for the poultry industry; it's also about the environment and water availability for future generations."

Moving from immersion to air chilling would also involve a change for the processing plant and a learning curve for its employees. "One of the biggest concerns for the poultry industry is cleaning and sanitizing the areas associated with air chilling. It is much easier to clean and sanitize an immersion-chilling system," says Northcutt.

Still, according to Northcutt, air chilling would save a minimum of one-half gallon of water for each bird processed. "Since 9 billion chickens were processed last year, that would equate to a savings of 4.5 billion gallons of water if all 9 billion birds were air chilled," she says. "But here's the catch: air chilling takes longer—90 to 150 minutes—than immersion chilling, which typically takes 50 minutes. If you consider time, energy cost, and yield, the two processes are economically equivalent."

Regulations May Tip the Balance

Water is at a premium in the Southeast, where residential and commercial users must compete for supplies. Stricter water regulations may help push conversion from immersion to air chilling. The rest of the Southeast is watching water restrictions in Georgia because it is the top broiler-producing state, at 1.3 billion chickens each year. Northcutt says that changes in Georgia typically affect the rest of the poultry industry.

"Currently there are seven plants in the United States that commercially air chill poultry and charge a premium price for the product. When air-chilled poultry products become commonplace, the price will drop, and there will no longer be an economic advantage to producing air-chilled poultry," says Northcutt.—By **Sharon Durham,** ARS.

This research is part of Food Safety (Animal and Plant Products), an ARS national program (#108) described on the World Wide Web at www.nps.ars.usda.gov.

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Two Fiji Dwarf (also called "Niu Leka") coconut trees (foreground) at the Subtropical Horticulture Research Station in Miami, Florida. The taller palm in the background is a Royal Palm.

Fiji Dwarf Sets New Durability Standards in Coconuts

Grown throughout the Tropics as a plantation crop, coconuts yield several important agronomic products, including the fruit and its processing byproducts. In the United States, coconut trees are a tropical ornamental plant that's highly in demand as a signature landscape element—particularly in Florida.

But in the 1970s, the lethal yellowing (LY) phytoplasma devastated the coconut canopy of South Florida and, by 1983, had destroyed about 100,000 coconut palms. Subsequently, the State of Florida Division of Forestry began a coconut-breeding program at ARS's Subtropical Horticulture Research Station (SHRS) in Miami to try to solve the problem. Its objective was to develop new LY-resistant varieties and establish seed orchards of known resistant cultivars. Coconut germplasm was received from the Jamaican Coconut Board for breeding and disease-management studies at both SHRS and the University of Florida's Fort Lauderdale Research and Education Center.

Strategies for managing LY focused on replacing disease-susceptible, tall coconut varieties with resistant dwarf types. When state funding ended, the germplasm collections of coconut persisted and eventually were incorporated into the National Plant Germplasm System.

When geneticist Alan Meerow joined ARS in 1999, he began to review the coconut germplasm at SHRS. Fiji Dwarf (also known as "Niu Leka") emerged as the prized jewel among the varieties because of its heavy, dense crown of short, dark leaves—features sought by ornamental growers, landscapers, and gardeners. Since then, Meerow and SHRS horticulturalist Tomas Ayala-Silva have continued to work with this variety with the tropical landscape horticulture industry in mind.

Fiji Dwarf's exact origins are unknown, but the oldest known introductions came from the South Pacific. It looks like a tall coconut variety with a swollen trunk base. It has outcrossing reproductive behavior—a process that introduces unrelated genetic material into a breeding line, which reduces the probability of individual palms being subject to disease or genetic abnormalities. Fiji Dwarf also bears large fruit but lacks bright-red-fruited and yellow-fruited phenotypes. It has shown variable resistance to LY in Florida, but it is free of the nutritional deficiencies that plague most other coconut varieties grown on Florida's relatively infertile soils.

Since 2001, the SHRS researchers have been using molecular tools to investigate the genetics of Fiji Dwarf and other varieties. Meerow and Silva want to know whether it's possible to identify an LY-resistant Fiji Dwarf genotype. So far, data indicates that Fiji Dwarf has the second-highest gene diversity among the varieties after the talls—such as Panama Tall—and the largest number of unique genes of any cultivar group within the study.

Moreover, in the past 8 years, not a single Fiji Dwarf has died of LY at SHRS. It is possible that the material now being cultivated at SHRS represents fully resistant stock, but further research needs to be done to confirm that. At present, there is no LY screening program at SHRS, so these observations remain anecdotal.

ARS scientists are now working with the Dade Chapter of the Florida Nursery, Growers & Landscape Association to develop seed-production orchards in South Florida with genotyped stock of Fiji Dwarf and perhaps other varieties.—By **Alfredo Flores,** ARS.

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

Jamaican Delicacy Makes a Comeback

Statistical research helped put ackee fruit back on U.S. grocery shelves.

Sweet ackees—the national fruit of Jamaica—are back in cans on U.S. retail shelves after an import alert had once again taken them off. That's partly because ARS agricultural engineer Thomas Whitaker provided a viable sampling plan to test the safety of the imported product. Whitaker is in the ARS Market Quality and Handling Research Unit in Raleigh, North Carolina.

Ackee fruit is smart because it knows how to defend its seeds until they mature to ensure a continued existence. When the fruit is still unripe, it contains a toxin, hypoglycin A, or HGA, that sickens anyone who dares to eat it. Because of the risk that unripe ackee containing HGA could enter the United States, the U.S. Food and Drug Administration (FDA) banned the canned fruit from import in 1973.

But the health hazard diminishes when the fruit is allowed to ripen completely before consumption or canning. So in 1998, the Jamaican government and several local processing firms developed safety plans to show they could control HGA. Only properly ripened ackees, without seeds, membrane, or outer rind, would be used in canning. The FDA inspected the processing firms and exempted them from the import alert.

"The first shipments came in 2000," says Joyce J. Saltsman with FDA's Office of Food Safety. But by December 2005, a variety of factors led to a series of safety-test failures. "The processing firms that had been exempted from the import alert were now back on automatic detention," says Saltsman. "Their food-safety systems needed to be reevaluated."

The only way that FDA could reestablish exemption status for any of the firms was to develop a monitoring program that balanced the cost of reducing the risk of accepting bad lots with the cost of an efficient sampling program. For that, they needed a statistical expert, and they found him in ARS's Whitaker.

"Among national and international commodity markets, he is considered an expert for his work in producing objective data on food toxins," says Saltsman. Whitaker's statistical analysis pointed to randomly selecting 10 cans out of each 1,000-can lot, combining the fruit pieces, and then testing the batch to see whether or not it exceeded the toxic tolerance level.

To arrive at this strategy, Whitaker measured the variability in HGA concentration among individual cans in a lot and found that as concentration within a lot goes up, so does variability.

"From the variability estimates, we predicted how much an increase in the number of cans to be inspected could reduce the risk of accepting lots that exceed the FDA limit," says Whitaker. A cost analysis revealed whether the expense of conducting the sampling was prohibitive. In this case, it was not."

WIKIPEDIA, JEROME WALKER (D1124-1)

Unripe ackee fruit is closed.

"FDA not only uses Whitaker's sampling plan, but so do Jamaican authorities and laboratories," says Saltsman. "We have once again exempted all the firms from the import alert, so they now ship product to the United States."—By **Rosalie Marion Bliss,** ARS.

WIKIPEDIA, DOC TAXON (D1124-2)

Ripe ackee fruit.

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

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Watch Your B's and Q's!

A New Whitefly's on the Move

STEPHEN AUSMUS (D288-23)

Whiteflies *(Bemisia tabaci)*.

A devastating tropical and subtropical pest—already considered a top invasive species—just got a bit more troublesome.

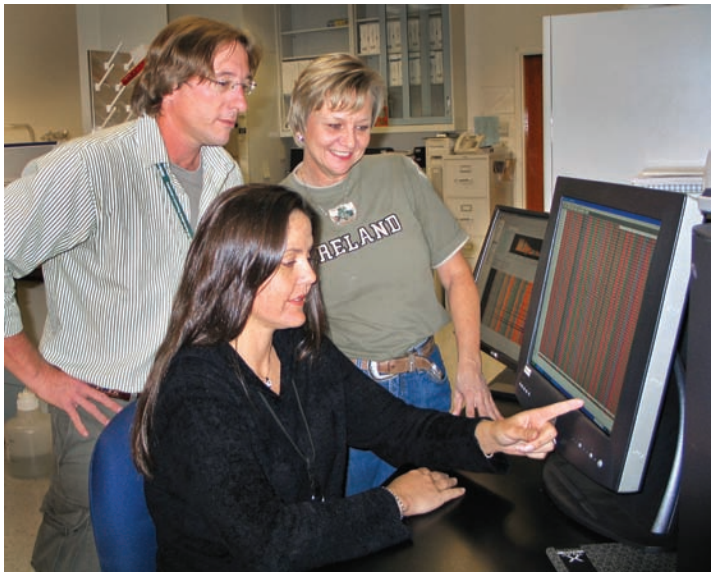
Bemisia tabaci is the scientific name for a collection of closely related whiteflies that are worldwide agricultural pests. There are more than 20 known biotypes of this species, with two of the most devastating to plants being the B and Q biotypes. Both can reduce yields of a broad range of agricultural crops.

The B biotype was first discovered in the United States in 1985, as a result of movement out of its native range of the Middle East/Asia Minor area. This aggressive biotype threatened agricultural production throughout the southern United States until new integrated pest management strategies brought it into check.

For years, researchers in ARS's Subtropical Insects Research Unit at Fort Pierce, Florida—including entomologist Cindy McKenzie and molecular biologists Bob Shatters and Laura Boykin—have studied the B biotype of *B. tabaci*. Now, however, a disturbing new whitefly discovery has their attention.

First detected in the United States on poinsettias from an Arizona retail outlet in December 2004, biotype Q has been identified in 25 states. Its native range is the Mediterranean Basin, and as with the B biotype, human transport of infected host plants is suspected in the introduction of these pests well beyond their home ranges.

DAVID MELIUS (D1097-2)



Molecular biologist Bob Shatters (left), entomologist Cindy McKenzie, and postdoctoral scientist Laura Boykin (foreground) study genetic polymorphisms in the whitefly *(Bemisia tabaci)* that are used to study the relationships among the B and Q biotypes. Associating these genetic markers with population traits provides a rapid means of tracking the movement of whitefly types.

In comparison to the B biotype, the Q biotype is less susceptible to many pesticide types, leaving fewer chemical options for control. There is also increased concern that insecticide resistance may develop more rapidly with Q. Making things more difficult, the Q biotype is indistinguishable in appearance from the B biotype.

"This was not welcome news when we first heard about it," says McKenzie. "But we've taken several steps to ensure that we'll be able to accurately distinguish between the two whitefly biotypes." As part of a nationwide task force studying movement of the Q biotype and related whitefly control issues, the ARS scientists have analyzed more than 3,000 individual whiteflies. The task force is composed of scientists from government agencies, universities, and private industry brought together to provide leadership in dealing with this new invasion.

Through the task force, samples of *B. tabaci* were sent to the ARS scientists by ornamental growers from sites throughout the United States. The researchers use DNA segments that provide unique signatures to distinguish between biotypes B and Q. When the Q biotype appeared in the United States, there was great concern that it may cross with the already well-established B biotype, producing an even more problematic pest. The genetic-marker work by the ARS scientists showed that there wasn't a single hybridization event observed between the two biotypes. Therefore, a "superbug" hybrid is unlikely to develop.

The task force, with the help of the ARS scientists, has developed new treatment recommendations—such as watching your neighbor's fields and getting your whiteflies biotyped—to deal with the Q biotype. Rapid implementation of these strategies has greatly reduced control problems and has helped to slow or prevent the Q biotype's movement into fields of vegetables. Knowledge of its whereabouts will aid more effective action to curb its spread and prevent serious economic losses, especially to the ornamentals industry.

Details of this research have recently been published in the journal *Molecular Phylogenetics and Evolution*. More information on biotyping whiteflies and sound management guidelines can be found at www.mrec.ifas.ufl.edu/LSO/bemisia/bemisia.htm.—By **Alfredo Flores,** ARS.

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

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2008 South Atlantic Area Award Winners

Area Senior Research Scientist of the Year

Ronald T. Riley
Athens, Georgia

For significant improvements in the science-based risk assessment of foodborne fumonisin mycotoxins and improved food safety through discovery of biochemical mechanisms and exposure biomarkers.

Herbert L. Rothbard Outstanding Early Career Research Scientist of the Year

Erica Spackman
Athens, Georgia

For timely development of rapid diagnostic tests for the control of important poultry diseases including avian influenza, Newcastle disease virus, and enteric viruses of turkeys.

South Atlantic Area Environmental Policy Statement

The South Atlantic Area (SAA) conducts research to develop solutions to agricultural problems of high national priority. In conjunction with this mission, the SAA is committed to protecting human health and the environment; meeting Federal, State, and local laws, regulations, codes, and guidelines; and employing sustainable pollution prevention practices. Whenever feasible, SAA employees will utilize pollution prevention initiatives as the means for achieving compliance. We will strive to minimize impacts and continually improve our environmental performance by:

- Maintaining a policy of commitment to environmental excellence.
- Developing annual goals, objectives, and targets to advance our program performance in terms of both regulated and unregulated impacts.
- Considering environmental impacts when making policy, planning, purchasing, and operating decisions.
- Identifying and complying with pertinent requirements in Federal, State, and local laws and regulations, permits, Department of Agriculture and ARS policies and procedures, and industry codes that we must adhere to.
- Making personnel aware of their environmental roles and responsibilities, providing appropriate training, and holding employees accountable for their performance and actions, including recognizing them for outstanding performance.
- Effectively communicating with employees, partners, stakeholders, customers, and the general public our commitment to the environment and soliciting their input in developing and achieving our goals and objectives.
- Routinely monitoring our environmental operations and conducting periodic inspections, audits, and reviews to ascertain that we meet applicable standards and to evaluate our program effectiveness.
- Correcting identified deficiencies in a timely manner and taking appropriate steps to prevent their recurrence.
- Clearly documenting and reporting the progress and achievements related to this policy.

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USDA, Agricultural Research Service (ARS) Website

http.www.ars.usda.gov

South Atlantic Area (SAA) Website

http://www.ars.usda.gov/main/docs.docid=6490 (on the website, click on the SAA location desired)

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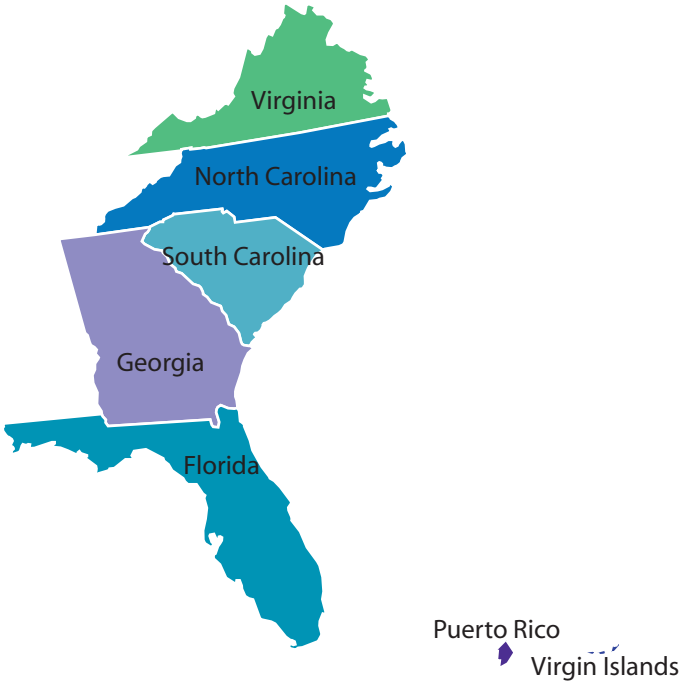
Cover 3



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