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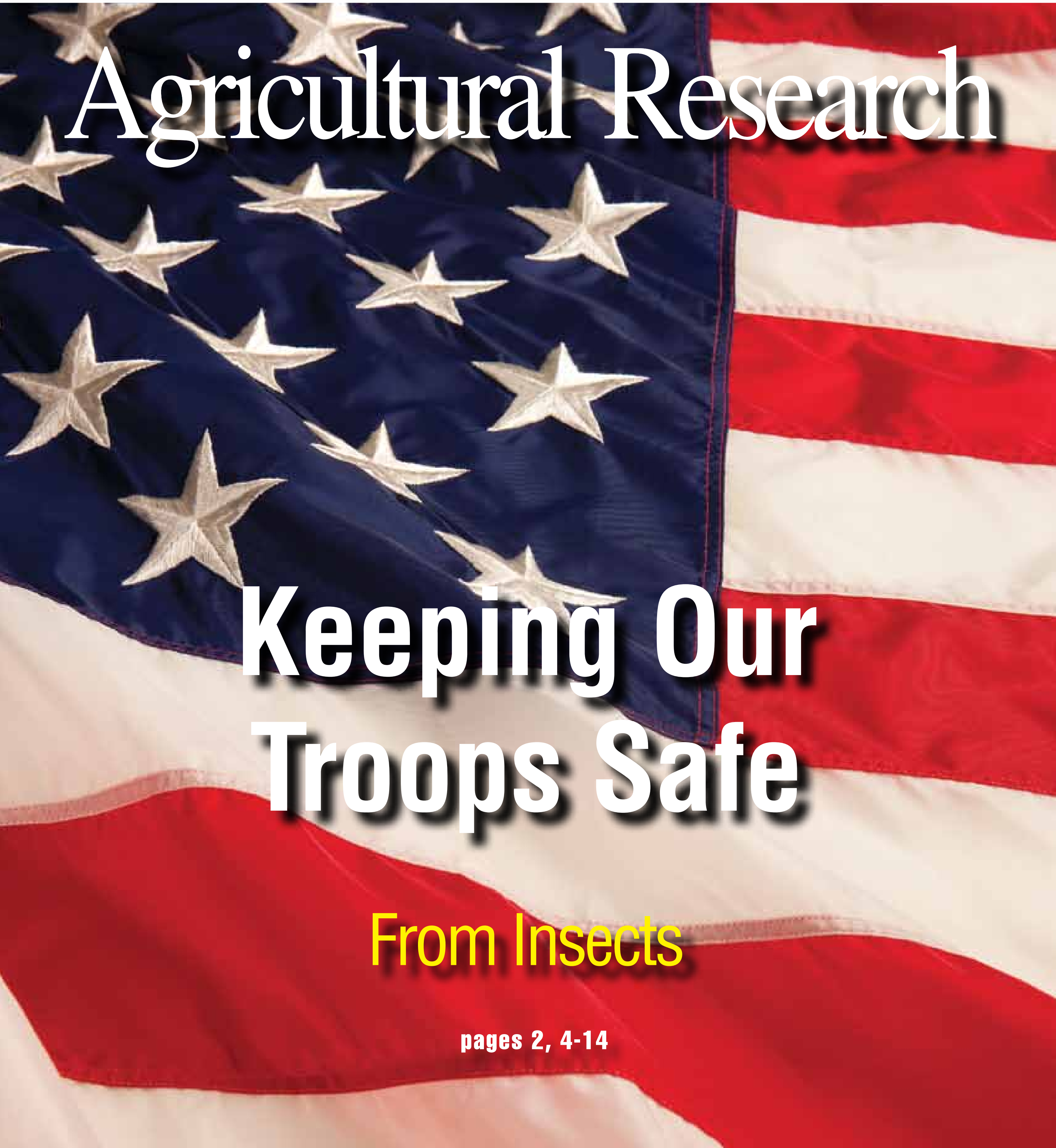

Keeping Our Troops Safe

From Insects

pages 2, 4-14

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

Products To Protect Consumers and the Military From Insects

Agriculture is about producing food, fiber, fuel, wood, and other essential products in a sustainable way. It is absolutely necessary for human life, and it makes us partners with natural processes that are the basis of growing plants and animals. That partnership means that agriculture is exposed to negative influences from nature, including threats from thousands of kinds of insects.

The U.S. Department of Agriculture has been extremely active for more than 100 years in finding ways to relieve the pressure from insects, motivated by the huge losses that occur when nothing is done about the problem. As a result, USDA has developed tremendous expertise in dealing with insect species.

The nation has called on this expertise repeatedly for help in managing nonagricultural pests. In the early 1900s, Leland O. Howard of USDA started the first guide to the mosquitoes of the United States, culminating in the classic work that reviews all mosquitoes of North and Central America. The guide was published between 1912 and 1917.

In 1941, the U.S. military asked USDA to support the war effort by developing products to protect personnel from insect-transmitted diseases, especially plague, malaria, scrub typhus, epidemic typhus, and dengue. The research led to repellents and insecticides that, for the first time, protected forces in the field, contributing significantly to the victory in both Pacific and European lands. Other accomplishments include the invention of the aerosol can, repellents for clothing and skin, insecticides for louse and mosquito control, and methods to eradicate malaria from the United States and other countries.

The U.S. Department of Defense continued to ask for help from USDA on insect-related problems, and the research provided solutions for termites, cockroaches, mosquitoes, and stored-product pests. This relationship took on new urgency after the turn of the millennium, as U.S. military personnel were being exposed to disease-carrying insects in Afghanistan and Iraq.

U.S. Navy Captain Gary Breeden, executive director of the Armed Forces Pest Management Board, and Ronald Rosenberg, a USDA-Agricultural Research Service national program leader for Veterinary, Medical, and Urban Entomology and a retired U.S. Army colonel, teamed up in 2004 to form a program they called "Deployed War-Fighter Protection" (DWFP). This program provides $3 million per year directly to ARS for the purpose of developing new ways to protect deployed military personnel from diseases transmitted by insects. DWFP also provides almost $2 million per year to universities, industry, and government to fund competitive proposals. (For more details on DWFP, see story on page 4.)

Discovering new insecticides for use against public-health pests like mosquitoes and sand flies has been the goal of a number of programs. DWFP has been particularly successful at discovering completely new kinds of insecticides and adapting existing ones to new conditions. The laboratories have used several strategies, including screening many chemicals for toxicity to mosquitoes, modifying known insecticides, examining substances derived from plants, and targeting specific physiological processes.

DWFP has the help of the Interregional Research Project No. 4 (IR-4) program, which is a USDA-financed operation that facilitates registration of minor-use pesticides. For 3 years, IR-4 has assisted with registration of public-health pesticides, thanks to funding from DWFP.

Personal protection from insects is particularly important to the military because war-fighters often find themselves in places where there is no possibility of areawide control. DWFP has supported USDA's work on developing new repellent active ingredients derived from plants, spatial repellents based on chemicals in our own skin, and new clothing treatments that provide protection from bites through the cloth and on adjacent exposed skin. Basic research on how mosquitoes locate hosts has raised the possibility of much more effective repellent active ingredients that would be game-changers for personal protection.

Scientific evaluation of insecticide application performed by ARS in cooperation with the U.S. Navy and industry partners has resulted in much better estimates of the right equipment for the right place. Sponsored by DWFP, an ARS laboratory has produced a smartphone application that makes selection of equipment much easier for the operator in the field. (See story on page 15.)

The ability of the U.S. military to deploy personnel anywhere in the world and to keep them healthy has been an important tactical advantage in every conflict. Protecting deployed war-fighters from insect-transmitted diseases is an important part of the preventive-medicine mission, avoiding the kinds of disasters from malaria, typhus, and plague that were formerly accepted as an inevitable part of warfare. An added benefit is that advances derived from this research may be useful for public and veterinary health as well.

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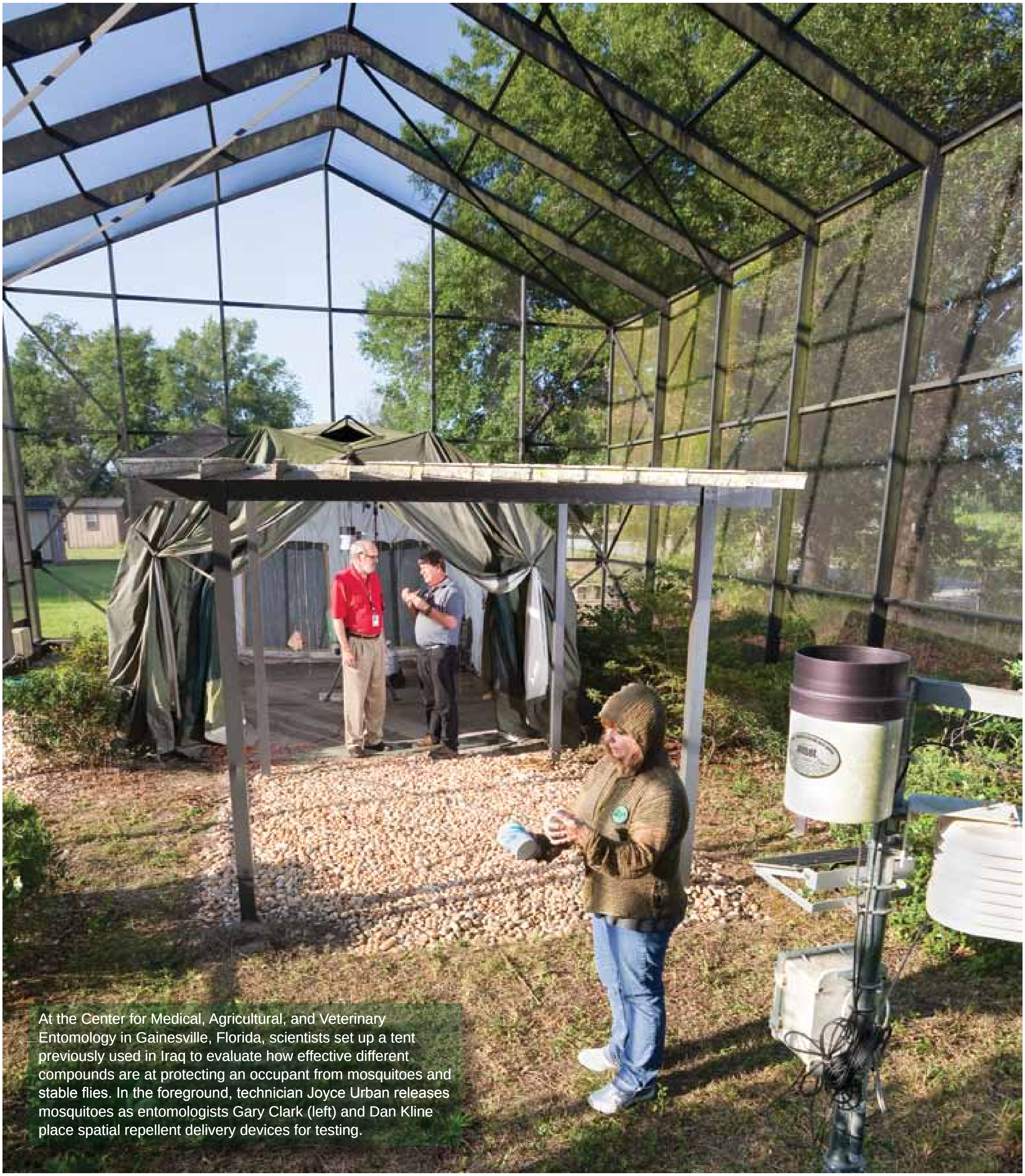
PEGGY GREB (D2696-1)

The dried inflorescence of the breadfruit tree is burned in some parts of the world to repel biting insects. ARS scientists are studying the compounds inside this interesting flower to find out what it contains and whether it might lead them to new repellents. Story begins on page 4.

Cover: USDA and the U.S. Department of Defense have partnered in the fight against disease-spreading insects since before World War II. In 2004, the Deployed War-Fighter Protection (DWFP) research program was implemented to prevent or defend U.S. troops from insect attacks. The story beginning on page 4 lists some of ARS's many DWFP research contributions that already benefit or may eventually benefit both soldiers and consumers. Photo by Peggy Greb. (D2700-2)

DWFP A Battle Plan To Protect

STEPHEN AUSMUS (D2627-12)



At the Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, scientists set up a tent previously used in Iraq to evaluate how effective different compounds are at protecting an occupant from mosquitoes and stable flies. In the foreground, technician Joyce Urban releases mosquitoes as entomologists Gary Clark (left) and Dan Kline place spatial repellent delivery devices for testing.

U.S. Troops From Harmful Insects

During World War II, U.S. Army General Douglas MacArthur was quoted as saying, “It’s going to be a very long war if for every division I have facing the enemy, I have one sick in the hospital and another recovering from this dreadful disease”—meaning malaria. Today, the battle against insects that cause disease is still being fought to help protect deployed U.S. troops and enable them to accomplish their mission.

Mosquitoes, sand flies, ticks, mites, and other biting arthropods transmit pathogens that cause some of the most devastating diseases. Malaria, dengue fever, yellow fever, Japanese encephalitis—all transmitted by mosquitoes—and a host of other diseases affect people around the globe and are a particular problem for militaries that send men and women to places where such illnesses are endemic.

For example, “In 2003, 80 out of 225 U.S. marines deployed on a mission to Liberia came down with malaria, but no deaths were associated with that incident,” says U.S. Air Force Lieutenant Colonel Douglas Burkett, research liaison officer with the Armed Forces Pest Management Board (AFPMB). “The trouble with most widely used insecticides is that we have fewer available active ingredients for public-health pest control, and at the same time, we have a global increase in insecticide resistance to our best chemical tools.”

The mission of the U.S. Department of Agriculture is critical to the U.S. Department of Defense (DOD), Burkett says. The Agricultural Research Service, USDA’s in-house research arm, has excellent research capabilities and is good at developing and testing pesticides and developing application technologies that support public health.

A strong alliance has long existed between USDA and DOD—as far back as 1932, when an entomological research laboratory was established in Orlando, Florida, to combat mosquitoes, filth flies, and disease-transmitting arthropods like fleas and mites.

STEPHEN AUSMUS (D2623-3)

The mosquito *Aedes aegypti* can spread several diseases as it travels from person to person. Only the females feed on blood. Above: This mosquito is just starting to feed on a person’s arm.

Below: The same mosquito has filled up on human blood. In partnership with the U.S. Department of Defense, ARS scientists are working to protect U.S. soldiers from this insect pest and other disease-spreading insects by developing new repellents, treated fabrics, and more.

STEPHEN AUSMUS (D2623-8)

“It was important to have a laboratory in an area where there were a lot of malaria vectors at that time,” says Ken Linthicum, director of the ARS Center for Medical, Agricultural, and Veterinary Entomology (CMAVE) in Gainesville, Florida. “During World War II, one of the laboratory’s objectives was to determine how to interrupt malaria transmission in the South Pacific to protect soldiers stationed there.”

Today, a new battle plan is under way. The Deployed War-Fighter Protection (DWFP) research program was implemented in 2004 to prevent or defend against insect attacks on troops. USDA receives $3 million of the $5 million allotted to the AFPMB by the U.S. Congress each year for research that focuses on developing public-health insecticides, improving personal protection for troops, and devising improved application technologies to kill insects. Remaining funds are distributed through competitive grants to universities, military laboratories, and private industry.

“Across DWFP, we have built a real strong network not only with the U.S. Department of Defense and the USDA, which is what this partnership is all about, but with universities, industry, and others,” says U.S. Navy Captain Stanton Cope, former AFPMB director and DWFP manager. “When you consider this program has only been in existence for a short period of time, its outreach and productivity are phenomenal.”

In the 1940s, USDA scientists at the Orlando lab, which was later moved to Gainesville and eventually became a part of CMAVE, developed delousing techniques that prevented millions of cases of louse-borne typhus, a disease with a high death rate and no effective treatment at that time. They also created the aerosol spray canister. Other achievements included the discovery of DEET by scientists at the Henry A. Wallace Beltsville Agricultural Research Center in Beltsville, Maryland. Today, DEET remains a primary defense against biting insects.

"DEET is still the best topical repellent we've got," Burkett says. "It has a long safety track record, but some soldiers don't like the odor and feel, and they prefer to have other options."

Initially, DWFP funds were to be used to bring together the skills of scientists at different ARS laboratories—starting with basic ideas that would end with registered products. This goal was mostly achieved, says Dan Strickman, ARS national program leader for Veterinary, Medical, and Urban Entomology. The research team includes 15 scientists at 5 ARS laboratories located in Florida, Maryland, Mississippi, and Texas.

"We're strongest in discovery and have developed entirely new classes of insecticides out of the DWFP program," Strickman says.

Unlocking the Chemistries of Folk Remedies

Some of those discoveries have come from plants gathered in the wild and from traditional folk remedies—two methods used by scientists at the Natural Products Utilization Research Unit in Oxford, Mississippi, to find plant-derived compounds to deter insects.

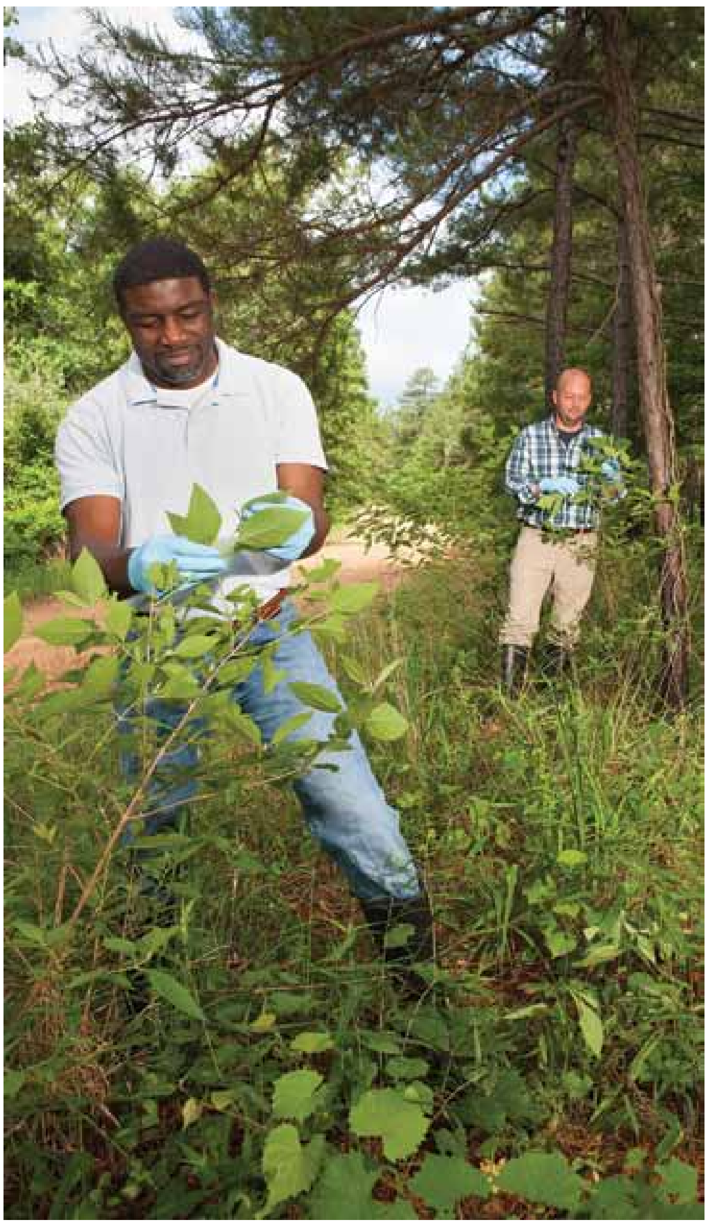
A story about a farmer in the 1930s crushing leaves of the American beautyberry plant and putting them under the harnesses of stock animals to keep pests away led to the discovery, in that plant, of the compound callicarpenal, which has significant repellency against mosquitoes and ticks. (See "Learning From Our Elders: Folk Remedy Yields Mosquito-Thwarting Compound," *Agricultural Research,* February 2006.)

Working closely with scientists at the ARS Mosquito and Fly Research Unit in Gainesville, Florida, and with Abbas Ali and others at the National Center for Natural Products Research at the University of Mississippi, chemist Charles Cantrell, plant pathologist David Wedge, and research leader Stephen Duke are exploring additional promising compounds from the American beautyberry and other plants to find natural alternatives that are as effective as or better than DEET at repelling arthropods.

Recently, Cantrell examined mosquito-deterrent effects of callicarpenal and looked at an efficient synthetic approach for commercial companies interested in producing it as an insect repellent.

Following up on a tip about people in Africa and India who burn *Jatropha curcas* seed oil in lamps to keep insects out of their homes and other areas, researchers identified which of the oil's components are responsible for mosquito repellency.

In the lab, smoke was extracted from burning *J. curcas* oil and analyzed. A number of active compounds—free fatty acids and triglycerides—were found to be effective at preventing mosquitoes from biting.



PEGGY GREB (D2693-1)

Left: Technician Solomon Green III (foreground) and chemist Charles Cantrell collect leaves from American beautyberry plants in a forest near Oxford, Mississippi. The leaves of the plant contain the mosquito-repelling compound callicarpenal.

Below: Charles Cantrell examines a burning dried male inflorescence from the breadfruit tree *(Artocarpus altilis).* People in Oceania routinely burned this plant to repel biting insects such as mosquitoes.

PEGGY GREB (D2695-1)

"Fatty acids are well known to have insect repellency," Cantrell says. "We identified the triglycerides as also having repellent activity, the first such report, to my knowledge."

Another possible source of repellents is breadfruit, which contains compounds similar to those in *Jatropha* sp. Cantrell hopes to combine the two sources into a more effective product.

One novel discovery is being kept under wraps for now. Chemist Kumudini Meepagala at the Oxford lab, collaborating with chemist Ulrich Bernier at Gainesville, has developed a natural-product-based mosquito repellent that is more active and lasts three times longer than DEET. A patent application has been filed on this undisclosed compound.

Learning How Repellents Hinder Mosquito Attacks

Another laboratory instrumental to the DWFP program is the Invasive Insect Biocontrol and Behavior Laboratory in Beltsville. Scientists involved in DWFP research there include chemist Kamal Chauhan, entomologist Joseph Dickens, and postdoctoral research associate Jonathan Bohbot. The group develops new chemical tools that are commercially viable and safe for humans, animals, and the environment.

In one study, Bohbot and Dickens sought to determine how the repellents DEET, 2-undecanone, IR3535, and picaridin produce their effects against the yellowfever mosquito. They found that these repellents affect specific odorant receptors in mosquitoes differently—scrambling the insect's ability to detect chemical attractants like octenol.

"We injected frog eggs with the odorant receptor genes that we're interested in, and the synthetic machinery within the eggs produced those receptors and put them in the outer cell membrane of the egg," Dickens explains. "We could then use tiny electrodes placed in the outer cell membrane to record electrical responses resulting from the presence of the odorant receptors."

The effects of the chemicals were then determined by flushing solutions of odorants or repellents over the eggs.

This cutting-edge technology enabled the Beltsville scientists to make a series of important basic discoveries with potential practical applications. Among those discoveries were the identification of the first mosquito receptor that could distinguish mirror images of molecules and individual proteins that recognize different attractants, and learning the way in which insect repellents scramble messages from chemical attractants.

Dickens says these new findings explain in part how repellents work and may be used to discover or enhance repellents in the future, based on their differential effects on specific odor receptors.

Outmaneuvering Mosquitoes

Much of the DWFP research takes place in the Mosquito and Fly Research Unit at CMAVE, where research leader Gary Clark; entomologists Dan Kline, Jerry Hogsette, Chris Geden, and James Becnel; and Bernier evaluate insecticides in the later stages of development and design innovative technology to fight biting insects and other pests.

Their work includes a rapid screening system for compounds to determine insecticidal possibilities, which was developed by Becnel's group. A patent was awarded for a molecular pesticide technology that kills mosquitoes by preventing them from producing proteins essential for survival.

ARS entomologist James Becnel (upper) and molecular biologist Al Estep (Navy Entomology Center of Excellence) inject nucleic acids into mosquitoes to "silence" specific genes.

NEIL SANSCRAINTE (D2645-2)

Another team member, entomologist Sandra Allan in the Insect Behavior and Biocontrol Research Unit at CMAVE, is using toxic sugar-based baits to lure and kill mosquitoes.

"You put this bait or trap out in the environment, and the mosquitoes or sand flies that want to sugar-feed come and feed on the bait, which contains pesticides that kill them," Allan says. "That's really important because mosquitoes and sand flies sugar-feed more often than they blood-feed."

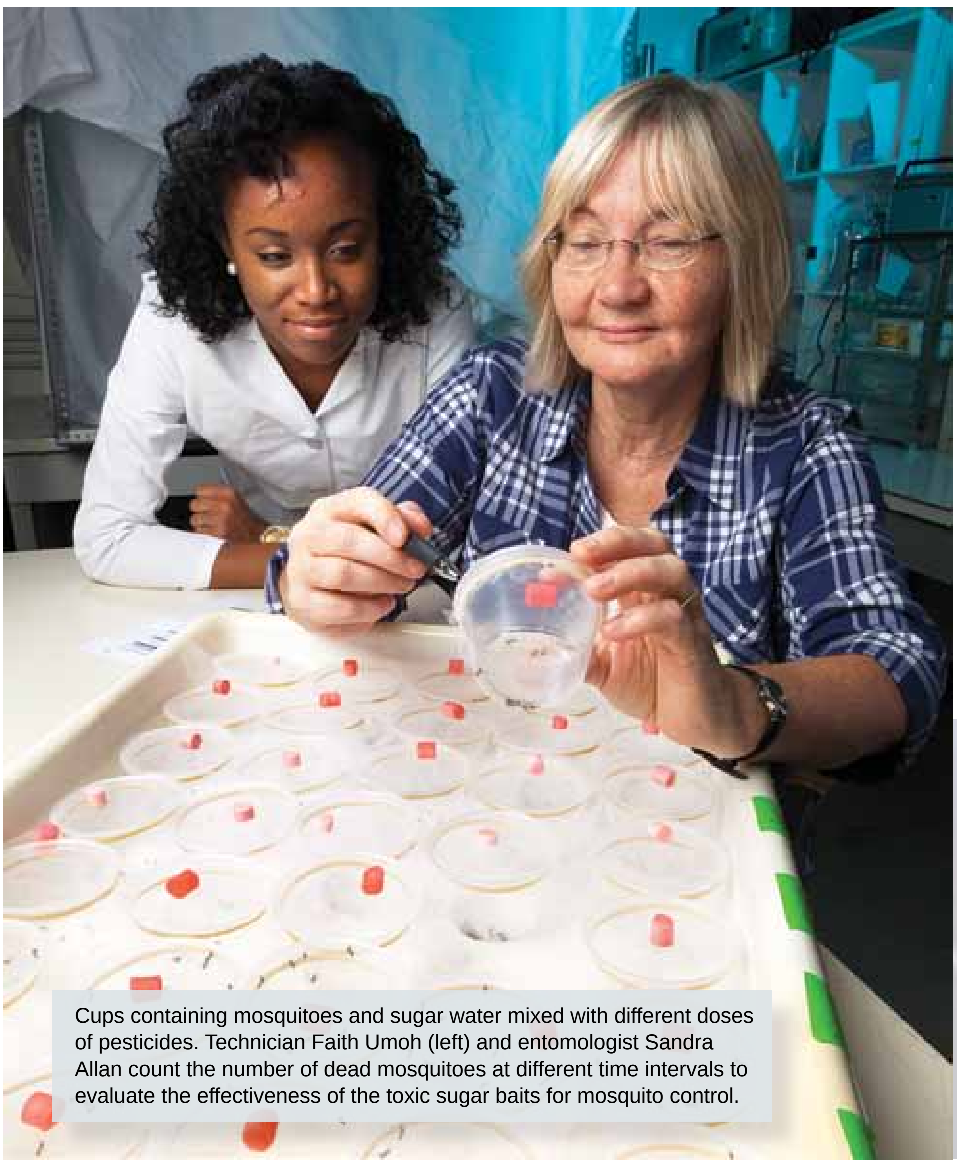
Only female mosquitoes blood-feed, whereas both males and females need to sugar-feed.

Allan looked at different commercial pesticides that include additives allowing them to be dissolved and ingested in water.

"That's important because when the mosquito feeds, it's actually drawing up the pesticide because it's water soluble," Allan says. "Also, using registered, commercially formulated pesticides puts us one step closer to developing end products and getting them out into the field."

In the study, 10 different insecticides were combined with a sucrose solution and fed to females of three mosquito species—*Culex quinquefasciatus,* which transmits West Nile virus; *Anopheles quadrimaculatus,* a malaria vector; and *Aedes taeniorhynchus,* an important pest and vector of some arboviruses.

Compounds from five different classes of insecticide active ingredients—pyrethroids, phenylpyroles, pyrroles, neonicotinoids, and macrocyclic lactones—were toxic to all mosquito species. These compounds could be used to develop toxic baits for the pests, Allan says. The next step is to evaluate these chemicals against sand flies and to determine if one is better than the others.



Cups containing mosquitoes and sugar water mixed with different doses of pesticides. Technician Faith Umoh (left) and entomologist Sandra Allan count the number of dead mosquitoes at different time intervals to evaluate the effectiveness of the toxic sugar baits for mosquito control.

STEPHEN AUSMUS (D2622-3)

New Recruits To Help Fight Sand Flies

STEPHEN AUSMUS (D2642-4)

A sand fly, *Phlebotomus papatasi,* can transmit parasites that cause leishmaniasis, a disease that can cause permanent skin damage and severe organ damage.

Sand flies are another major pest for troops in the Middle East, Afghanistan, and Africa.

"I was one of those guys deployed to Iraq in 2003," Burkett says. "I'm an entomologist. I know how to control sand flies, because I've read all the textbooks. The reality is, when we got there, nothing worked. Soldiers were getting between 100 and 1,000 bites per night from sand flies that were testing positive for the parasites that cause this hideous disease, leishmaniasis."

There are no vaccines or medications to prevent leishmaniasis, nor any way of telling whether a soldier has it until 3 or 4 months after being bitten by a sand fly infected with *Leishmania* parasites, Burkett says. Victims of the disease commonly suffer with permanent skin disfigurement and sometimes severe organ damage.

Two years ago, scientists at the ARS Knipling-Bushland U.S. Livestock Insect Research Laboratory in Kerrville, Texas, joined the DWFP team to help find ways to kill sand flies. Entomologists Andrew Li, Adalberto Pérez de León, and their colleagues started a sand fly colony to evaluate new insecticides and repellents, develop formulations, and design diagnostic tools for rapid detection of resistance.

"Our project focuses on screening insecticides that are available on the market to see which ones are more effective," Li says. "The information we gain will be helpful to the military and the public in choosing insecticides to control the sand fly."

Only a few studies have addressed sand fly resistance to pesticides, so Li is looking at sand fly genes to find answers. He is developing a test for detecting mutations responsible for resistance.

Another laboratory looking for solutions is the ARS European Biological Control Laboratory in Thessaloniki, Greece. With funds from the DWFP program, ARS hired Alexandra Chaskopoulou, a native of Greece and a postdoctoral research associate, who is examining sand fly populations that transmit leishmaniasis in her country.

Fighting Filth Flies

(D2620-1)

The adult stable fly, *Stomoxys calcitrans,* is one of many biting, blood-feeding insects.

Nonbiting flies that shuttle between filth and food spread bacteria that cause diarrhea, the most common reason for absence from duty in the U.S. military.

"In my experience in the military, every time there was an outbreak of flies, there was an increase in the disease rate and a big increase in diarrhea," Strickman says. "When we controlled flies, we brought that down."

Not to be outflanked, scientists are working with a number of products and techniques that involve testing new traps, finding insecticides that work, and developing new methods to control this nuisance.

CMAVE's Geden recently teamed with researchers at an Australian public-health agency to determine whether an insect growth regulator called "pyriproxyfen,"

At Gainseville, Florida, entomologist Chris Geden sets up an autodissemination device for flies in an outdoor screenhouse. Flies are attracted to the device by an olfactory lure and become covered with pesticide dust, which they carry back to larval development sites.

STEPHEN AUSMUS (D2619-4)

STEPHEN AUSMUS (D2628-4)

Entomologist Jerry Hogsette sets out stable fly traps and targets for a field study. Stable flies breed in manure, wet straw, and decaying vegetation, and they feed on the blood of livestock and people. Expertise gained in field tests for controlling these flies and other biting insects helps ARS scientists find the best insect controls for the military, farmers, and consumers.

which was successful in controlling mosquitoes, could also kill house flies.

"Pyriproxyfen mimics a hormone in the larval fly," Geden says. "When it's applied in sufficient quantities to larval breeding sites such as manure, insects become stuck in the immature stages and they never become adults."

The greatest potential for pyriproxyfen may be via autodissemination, a process in which adult flies are treated with pyriproxyfen that they later transport to egg-laying sites, he says.

Geden treated gravid females—those with eggs—with a dust containing pyriproxyfen and then allowed the flies to lay their eggs on a larval medium. All immature flies died in the pupal stage. This approach would eliminate broadcast application of the insecticide and take advantage of fly behavior to deliver the pyriproxyfen to targeted larval-breeding sites, Geden says. Scientists looked at the dosages required to kill house flies, the potency needed, different formulations, and the amount a fly can carry to the larval habitat.

"We found the material extremely effective at low dosages for house flies and that flies are capable of carrying enough back to their breeding sites to prevent the maturation of immature flies," Geden says. "We're now working with new formulations of higher potency to improve this system."

On a different front, CMAVE's Hogsette is working with University of Florida scientists to find more effective methods for baiting and trapping flies.

"House flies can use a wide range of larval development media—almost anything that's moist—and can develop from the egg to the adult stage in just 6½ days," Hogsette says. "Multiple traps may be required at capture sites to effectively reduce house fly populations, but research is needed to determine just how many are needed."

What To Wear

Factory-treated uniforms that repel insects are the latest in protective fashion for deployed troops. Attachable bands that offer additional protection may be in style for the future.

"The more proficient we are at repelling or killing insects, the better our ability to prevent disease transmission to our troops when they are deployed," Bernier says.

Bernier and textile chemist Melynda Perry of the U.S. Army Natick Soldier Systems Center evaluate the quality of permethrin-treated uniforms and fabric. The testing-and-evaluation process is an outcome of efforts made in 2003 by the U.S. Marine Corps to stock combat uniforms that were factory treated with permethrin. The initial specifications to qualify permethrin-treated uniforms were drafted in 2006.

Research on U.S. Army uniforms is conducted by Bernier, Perry, and Neal Nguyen of the Program Executive Officer Soldier at Fort Belvoir, Virginia.

Treated uniforms have been standard practice since 1951, when an ARS-developed miticidal mixture, M-1960, was used. M-1960 was discontinued in 1982 because it was a skin irritant. ARS scientists developed a permethrin treatment of uniforms, and field treatment of cotton uniforms with this repellent became available in 1991.

Since then, new uniforms have been introduced, and many incorporate fire-resistant fibers. Application of permethrin to these uniforms is not possible without factory treatment.

Bernier developed a bite-protection assay to test how well uniforms protect the wearer from mosquito bites. It requires that a human volunteer wear a tightly sewn uniform sleeve and then insert the covered arm into a cage of mosquitoes.

"We use human volunteers because, in the real world, humans wear these uniforms," Bernier says. "It's far better to figure out the best treatment here at home, before the uniforms are worn in the field and we end up having missions fail."

"I was one of those guys deployed to Iraq in 2003. I'm an entomologist. I know how to control sand flies, because I've read all the textbooks. The reality is, when we got there, nothing worked. Soldiers were getting between 100 and 1,000 bites per night."—Douglas Burkett

Uniform fabric specimens are tested to determine their ability to provide protection initially and after 20 and 50 launderings. So far, a total of 65 U.S. military uniform constructions and compositions have been evaluated.

In 2011, scientists examined alternative fabrics for potential replacement of the original fire-resistant Army combat uniform. Fabric replacement was necessary because the material initially selected was too easily torn. Earlier this year, Bernier completed bite-protection testing on uniforms constructed of this more durable fire-resistant fabric.

Bernier and chemist Chauhan have created an attachable repellent-treated band that augments the uniform by conferring some spatial protection to exposed skin. Preliminary evaluations indicate that the band may have additional use for travelers against bed bugs, Chauhan says.

"We've achieved protection for the uniform, but our ultimate goal is a stand-alone product, so even without the uniform, you can put the band on the sleeve or collar to protect that area for a long period, and it can be used again and again," Chauhan says.

The U.S. military treats uniforms with permethrin to prevent mosquitoes and other insects from biting. At Gainesville, Florida, chemist Ulrich Bernier (right) tests a treated uniform to see whether it prevents mosquitoes from biting. In the background, technician Greg Allen studies how well mosquitoes are attracted to various test substances.

STEPHEN AUSMUS (D2624-2)

Chauhan has filed for a patent on another new product—a disposable, reversible bandage—for short-term protection. The invention also has potential application for recreation and sports use and as a device to protect pets and livestock from biting insects.

Rounding Up the Best Equipment

Each year, ARS scientists at the Southern Plains Agricultural Research Center (SPARC) in College Station, Texas, pack up and head off to an equipment rodeo—the Annual International Equipment Evaluation—at the Navy Entomology Center of Excellence (NECE) at Jacksonville Naval Air Station in Florida.

The team from NECE and the SPARC Areawide Pest Management Research Unit's Aerial Application Technology group "round up" sprayers of all shapes and sizes—hand-held, backpack, truck-mounted, and thermal foggers with water and oil-based sprays and insecticides—used in insect-control applications.

"Manufacturers operate their own equipment, and all testing is done out in the open," says SPARC agricultural engineer Clint Hoffmann. "The good and bad results are published on all equipment tested."

So far, the group has developed droplet size spectra for about 88 sprayers.

"We think we've tested every piece of equipment that's in the military arsenal," Hoffmann says.

"Adding this group of engineers that work with droplets and machinery has given a huge boost to this program," Burkett says. "They have a lot of expertise for area application sprayers, and they find out

> "Whenever you get a new compound that works well in the laboratory, you have to take it to the field to make sure it's useful in the real world."
>
> —Dan Kline

At a remote patrol base in Iraq, ARS scientist and U.S. Army medical entomologist Seth Britch applies a residual treatment of lambdacyhalothrin to camouflage netting and shade cloth that will be suspended over outdoor eating and cooking areas and over areas in between dormitories. This residual pesticide treatment reduces populations of biting flies and mosquitoes by transferring lethal doses to the insects when they rest on the camouflage material while seeking human hosts.

SETH BRITCH (D2643-1)

SETH BRITCH (D2644-1)

In Marigat, Kenya, Kenneth Linthicum, the director of ARS's Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, calibrates a thermal fogger in preparation for experimental applications of aerosol pesticides to control sand flies. The trials at Marigat use both ultra-low-volume and thermal fog equipment and a variety of EPA-labeled pesticides and are the first of their kind in providing critical information to better target sand flies in hot, arid locations.

what works and what doesn't, which is a great benefit to the military."

Scientists use the most accurate measuring tool, a laser diffraction instrument, to measure spray droplet sizes, test active ingredients, and capture data. Studies have led to the development of a user-friendly smartphone application that can be downloaded to help users select spray equipment and optimize spray settings, says agricultural engineer Brad Fritz. (See story on page 15 for details.)

Taking It to the Field

"Whenever you get a new compound that works well in the laboratory, you have to take it to the field to make sure it's useful in the real world," says CMAVE's Kline.

Spatial repellents are used in field conditions to significantly reduce the number of mosquitoes and other biting insects in a specific area over a certain period of time, he says. The criteria for insecticides depend on the situation.

"For example, the individual soldier may be on sentry duty, not moving," Kline explains. "Special operations teams may be hiding out, looking for terrorists. Then you may have a community of soldiers in a tent or encampment where dimensions may vary."

In one experiment, scientists set up tents previously used in Iraq to evaluate how effective different compounds are at protecting an occupant from mosquitoes and stable flies. (See photo on page 4.)

"Many of the applications tested were not practical for soldiers, which is why there's a need for a better delivery system and one reason why treating uniforms with compounds is critical," Kline says.

"We go to a desert, like the Coachella Valley in California, that is similar to desert environments in the Middle East where U.S. troops are deployed," says Linthicum, "and we're able to evaluate the effectiveness of various equipment and treatment methods."

Tents, camouflage screening, sun awnings, and other structures of deployed units can be treated quickly using spray equipment currently issued to preventive-medicine units, Linthicum says.

Studies have shown that insecticide treatment of woodland-pattern military camouflage netting is long lasting and effective at reducing mosquitoes. Seth Britch, an entomologist at CMAVE and a captain in the U.S. Army Reserve, demonstrated that desert-pattern camouflage netting can also be treated to provide effective protection against mosquitoes and sand flies in a hot, arid environment.

The study involved spraying specially formulated insecticides onto the netting. Once dry, the residual treatment forms a barrier that is toxic to insects, Britch says.

The material was then packed in a conex cargo container and shipped to Tallil Air Force Base in Iraq, where it was stored for 5 months and then tested from March-June 2010. The netting was sent back to CMAVE for analysis.

"After almost 300 days, we were still getting good control of mosquitoes," Linthicum says.

In another experiment, Britch, Linthicum, and Todd Walker, an entomologist formerly with NECE, evaluated the performance of ultra-low-volume pesticide spray equipment, chemicals, and techniques in Kenya against sand flies for the first time. They tested two pesticide sprayers and two pesticides against wild and colony-reared sand flies as proxies for similar sand fly species and similar environments found in Iraq and Afghanistan. They demonstrated that current DOD equipment and one pesticide performed well against sand flies in a hot, arid environment.

Getting Products to Troops

Using funds from the DWFP program, ARS and the Interregional Research Project No. 4 (IR-4) signed a cooperative agreement to establish the IR-4 Public Health Pesticides Program to facilitate registration of new uses of chemicals.

"One of the reasons the IR-4 project was brought into the mix is because we have worked in the public sector almost 50 years to provide an avenue to get these minor-use products into the hands of IR-4's traditional stakeholders—the growers of fruits, vegetables, herbs, and other specialty crops," says Jerry Baron, executive director of the IR-4 project.

The roles of IR-4 are to make sure insecticides are safe, to work with the U.S. Environmental Protection Agency in getting products registered, and to find active ingredients that already have registrations for other purposes that may have public-health applications, says Karl Malamud-Roam, manager of the IR-4 Public Health Pesticides Program.

"We work hard to maintain registration of existing, useful public-health products and to ensure that the registration process is as smooth and efficient as possible," Malamud-Roam says.

> "We go to a desert, like the Coachella Valley in California, that is similar to desert environments in the Middle East where U.S. troops are deployed, and we're able to evaluate the effectiveness of various equipment and treatment methods."—Ken Linthicum

There are many good ideas in the minds of scientists, military experts, and academic and industry partners, and in chemical libraries, Malamud-Roam says. There's also a product-development pipeline that sometimes gets clogged.

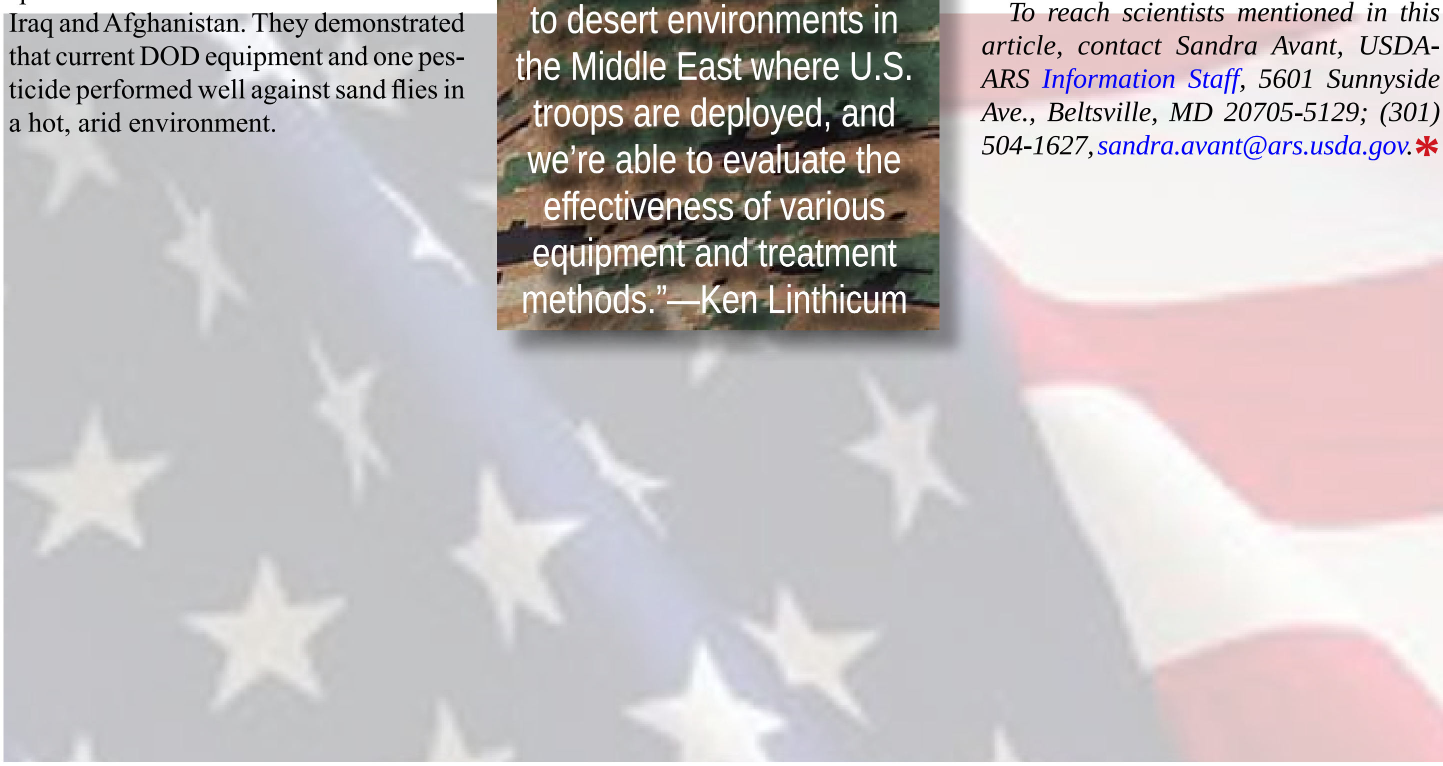
"IR-4 has traditionally been like a regulatory plumber," he says. "Our job is not to make discoveries, like new molecules. We leave that to other scientists. Our job is to figure out how to get molecules from the idea stage to product registration."

More than 330 scientific papers have been published by researchers since the DWFP program began. Most of this research, about 81 percent, is the work of ARS scientists.

"This is what it's all about," Burkett says. "This is what keeps programs alive. When funds are put into research programs like DWFP, discoveries are made, collaborations are built, and it actually results in tangible products that we can get into the hands of soldiers to kill bugs."—By **Sandra Avant,** ARS.

This research is part of Veterinary, Medical, and Urban Entomology, an ARS national program (#104) described at www.nps.ars.usda.gov.

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



BRAD FRITZ (D2697-1)

Spraying Insecticide?

There's an App for That!

Two new apps developed by ARS scientists in College Station, Texas, are now available to provide aerial and ground-based crews with specifics on best choices—from airspeed to type of sprayer to nozzle type—for applying pesticides. The apps can be used on smartphones or tablets.

Applying pesticides is no simple task. With dozens of manufacturers producing dozens of different types of spray technology—each with its own nozzle type, flow rate, and pressure setting range—the equipment can get pretty complicated. Adjusting equipment to the right settings can involve factoring in wind speed, air temperature, flight speed, and humidity.

Agricultural Research Service scientists in Texas have released two new applications, or "apps," to make things easier. The apps, developed by Brad Fritz and Clint Hoffmann, who are with the Areawide Pest Management Research Unit's Aerial Application Technology group in College Station, will ensure that aerial and ground-based crews that spray pesticides have the best guidance possible before they spray. Users key in specifics on the type of equipment and pesticide they are using. The app displays the droplet size that will result from that setup and allows users to tweak settings to generate the desired droplet size.

The apps are designed to tap into the increasing use of smartphones and tablets. The National Agricultural Aviation Association found that more than half of the aerial applicators who responded to a recent survey reported using smartphones as their primary mobile device. The survey found an even split between Androids and iPhones, and the apps can be used on either device, Fritz says. "We have all this good data available, and we wanted to provide a convenient, easy-to-use platform that provides the data to the applicators who need it," he says.

The apps incorporate the latest science of spray technology, including "spray nozzle atomization" models developed by ARS at College Station. The apps can be accessed from the field or from the cabin of a small aircraft, and they allow users to save data for later use or e-mail it to colleagues.

One app is designed for ground-based spraying for mosquitoes and other threats to public health. It covers 60 different sprayers made by 19 manufacturers and was developed jointly with the U.S. Department of Defense's Navy Entomology Center of Excellence in Jacksonville, Florida. The ultra-low-volume sprayers and foggers range from hand-held and backpack types to ones mounted on all-terrain vehicles and trucks.

This public-health project was funded by the Deployed War-Fighter Protection program, which is administered by the Armed Forces Pest Management Board. The board funds ARS efforts to develop methods to protect military personnel from insect-transmitted diseases. (See story beginning on page 4.)

The aerial spray app walks users through the process of adjusting nozzles and settings. The user specifies the nozzle manufacturer from a menu and is then steered through a series of screens and prompts. Based on the specific operating conditions, the app helps the user select the right size nozzle opening, spray pressure, nozzle orientation, and airspeed so that pesticides are delivered at the desired droplet sizes. Droplet size is critical in aerial operations to ensure accuracy, minimize pesticide drift, and ensure product label compliance with many agrochemical products. The app includes data on 10 fixed-wing spray nozzles and 8 rotary-wing nozzles. Fixed-wing models cover airspeeds from 100 to 160 mph, while rotary-wing models cover 30 to 100 mph.

The apps are available online through the Apple iTunes App Store and the Android Market by searching for "Aerial Sprays" for the aerial application app and "Vector Sprays" for the ground-based sprayer app.—By **Dennis O'Brien,** ARS.

This research is part of Crop Protection and Quarantine (#304) and Crop Production (#305), two ARS national programs described at www.nps.ars.usda.gov.

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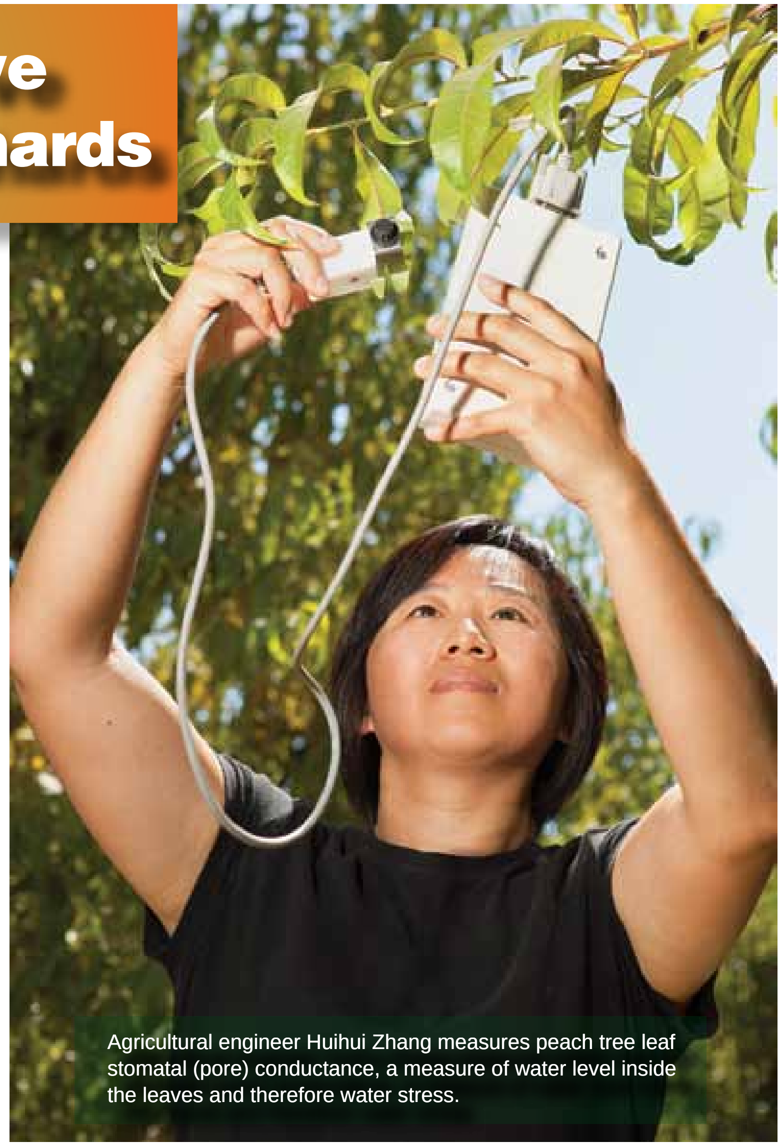
Finding Ways To Save Water in Peach Orchards

PEGGY GREB (D2683-1)



Agricultural engineer Huihui Zhang measures peach tree leaf stomatal (pore) conductance, a measure of water level inside the leaves and therefore water stress.

A team of Agricultural Research Service scientists in Parlier, California, is focused on helping peach growers in the San Joaquin Valley reduce the amount of water they use in ways that won't affect yield or quality.

Water is a major issue in the valley, and raising peaches there requires a lot of it. Early-season peaches are normally harvested in late May and early June, but the trees take most of their water from June through September—the time of year when temperatures and water demands are at their highest. Irrigation is the only source of water for agriculture during the summer, and while snow packs in the Sierra Nevada have traditionally been a sufficient source for peach growers, earlier snowmelts have made water even more precious. Wells drilled to supply the valley with water in recent years have had to reach deeper and deeper to bring up enough water to meet increasing demands.

Dong Wang and James E. Ayars, in the Water Management Research Unit at the San Joaquin Valley Agricultural Sciences Center, are finding ways to reduce water use in the tree's postharvest phase using two different approaches. "With peach trees, the issue is that over two-thirds of the water is applied after harvest. We're looking for ways to reduce that," says Wang, who is the unit's research leader. Their "deficit-irrigation" studies are designed to ensure continued productivity of an estimated 25,000 acres of peach orchards in the San Joaquin Valley. Deficit irrigation means supplying less water to a plant than it would normally need to stay healthy under optimal conditions. The goal is to minimize the impact on yield by using deficit irrigation during select stages of growth so that the water stress is corrected at other times of the year, such as in the winter and spring, Wang says.

In his experiments, Ayars studied the effect of deficit irrigation on a 4-acre plot of trees that produced Crimson Lady peaches, an early-harvest variety. He irrigated the trees from March to the May harvest. Then, in the postharvest phase, between June and September, he gave the trees either 25 percent of the normal amount of water, 50 percent of the normal amount, or 100 percent. He measured soil water content once a week to be sure that even with periodic rainfall, trees were given the appropriate deficit-irrigation treatments. He also followed standard commercial practices for fertilization, pruning, and fruit thinning and used three types of irrigation systems in the study: microspray, subsurface drip irrigation, and furrow, where water is distributed in shallow canal-like rows near the tress. At the end of each harvest, all defective fruit were counted and removed; and the remaining fruit were counted, weighed, and mechanically sized.

The results, submitted for publication in *HortScience,* show that when you reduce postharvest irrigation to 25 percent of what is normally applied, there is a negative impact on the following year's fruit yield and quality, and there are more deformities of the fruit. But the results also showed that by giving trees 50 percent less water, growers could see a 60 to 69 percent savings of postharvest water use with minimum effect on the following year's fruit quality and yield. The subsurface drip irrigation systems tended to have the lowest yields within a given year, but the differences were generally not statistically significant. The researchers also found that trees needed less pruning and maintenance because deficit irrigation slowed plant growth. "Most of the water savings we saw occurred during the hottest part of the year, when demand for water is highest, so there's a real potential for savings," says Ayars.

Deficit irrigation has been used to produce some varieties of grapes and has been studied for its potential in fruit tree and row crop production. But it has yet to be widely adopted, in part because growers need better tools to strike a balance between saving as much water as possible and keeping crops viable and healthy, Wang says. "When crops are managed under deficit irrigation, the margin of error is much smaller in terms of avoiding yield losses from any missteps in the amount of water applied or in the timing of the application," he says.

Sensing Trees' Water Needs

Wang and Jim Gartung, an ARS agricultural engineer in Parlier, are evaluating whether infrared sensors and thermal technology can help save water by determining precisely when peach growers need to irrigate their orchards. Infrared sensors go back to the 1970s and have been used to monitor the health of cotton and other crops.

Wang and Gartung installed 12 infrared temperature sensors in the same peach orchards used by Ayars. Over 2 years, they gave trees any one of four irrigation treatments: furrow or subsurface drip irrigation with or without postharvest water stress. They also measured crop yields and assessed fruit quality to compare the output of trees growing under deficit irrigation with trees growing under normal irrigation conditions.

When temperatures rise, the loss of water vapor from the leaves cools the plant. But when water loss from the leaves exceeds what the roots are taking up from the soil, the leaves' microscopic pores, called "stomata," begin to close up. Although this can conserve water in the plant, less heat is carried away by water vapor, resulting in a warmer tree, which also contributes to water stress, Wang says. "If the leaves of a tree are dry and water stressed, they will not be transpiring the way they should be, and the temperature in the tree canopy will be higher. The infrared sensor measures the temperature of the leaf canopy, which reflects the overall thermal footprint of the tree," Wang says.

They used the sensors to measure temperatures in the tree canopies and calculated a "crop water stress index" based on the differences between tree canopy temperatures and the surrounding air temperatures. Higher index numbers indicated more-stressed trees. The researchers found that midday canopy-to-air temperature differences in trees that were water stressed postharvest were in the 10° to 15°F range, consistently higher than the 3° to 4°F range found in the trees that were not water stressed.

How Much Pressure Can a Leaf Take?

Another way to determine whether a tree is water stressed is to measure its "stem water potential," which is the ability of the leaf to hold water. The researchers determined stem water potential of the stressed and nonstressed trees by putting their leaves in a pressure chamber and measuring the pressure required to squeeze water out of them. When the trees are water stressed, it takes more pressure to squeeze moisture from them, Wang says.

The results, published in 2010 in *Agricultural Water Management*, show that the measurements of stem water potential were consistent with data collected by the infrared sensors, which means the sensors may be an effective tool for managing deficit irrigation in peach orchards and helping growers decide when to irrigate, Wang says.

DONG WANG (D2686-1)

Infrared thermometer mounted on a pole for measuring peach tree canopy temperature under regulated deficit irrigation. Stressed leaves have a higher temperature than nonstressed leaves.

In the second phase of the project, the researchers are focused on identifying specific levels of water stress that peach trees can tolerate and teasing out relationships between that stress and canopy temperatures. They hope to develop an algorithm or formula that growers could apply to different water-stress scenarios to reduce water use year after year.

"We've proved that this is a viable approach to managing deficit irrigation in peaches. Now we want to give growers the tools they need to use it," Wang says.—By **Dennis O'Brien,** ARS.

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

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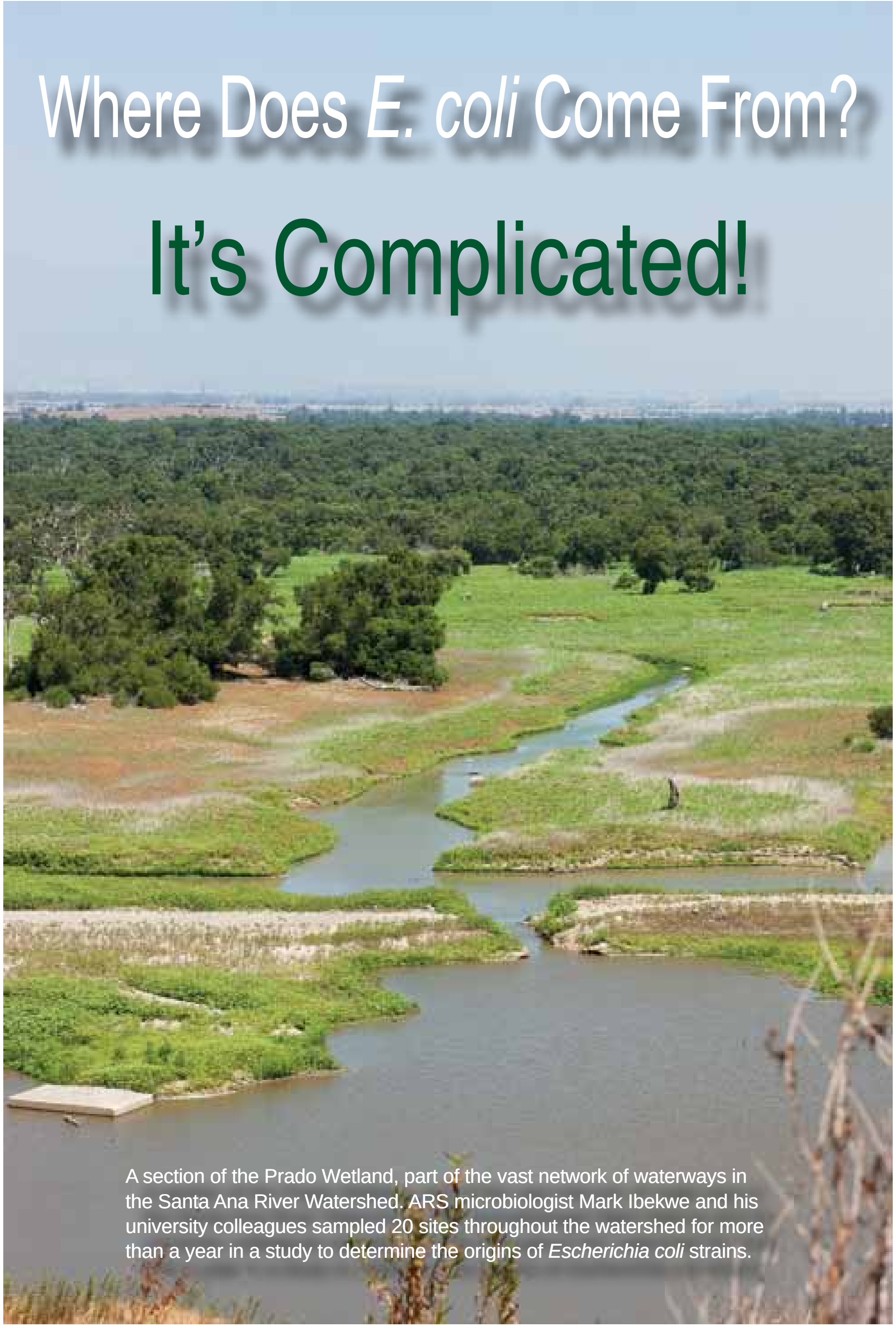
PEGGY GREB (D2680-1)

Soil scientist Dong Wang examines leaves of peach trees that underwent postharvest deficit irrigation.

PEGGY GREB (D2691-1)

Where Does *E. coli* Come From?

It's Complicated!



A section of the Prado Wetland, part of the vast network of waterways in the Santa Ana River Watershed. ARS microbiologist Mark Ibekwe and his university colleagues sampled 20 sites throughout the watershed for more than a year in a study to determine the origins of *Escherichia coli* strains.

"People blame cows for so many things," says Agricultural Research Service scientist Mark Ibekwe.

However, Ibekwe has now identified telltale links between the *Escherichia coli* bacteria living in the streams and sediments of one southern California watershed and their origins—findings that could help restore the reputation of the local livestock. His studies suggest that the pathogens that end up in local waterways are more often carried there via runoff from urban areas, not from animal production facilities.

Public-health officials use *E. coli* as an indicator of water quality, and cows are often seen as the culprits when *E. coli* is found in local lakes, rivers, and other bodies of water. The bacteria can survive in surface water and sediment because of high nutrient content from manure from livestock facilities, runoff from residential areas, warm temperatures, and inputs from other urban sources. Even though most strains of *E. coli* are nonpathenogenic, bacterial counts in the Santa Ana River Watershed have exceeded U.S. Environmental Protection Agency water-quality standards.

Ibekwe, who works at the U.S. Salinity Laboratory in Riverside, California, studied hundreds of *E. coli* isolates he collected from the middle Santa Ana River Watershed to determine their source. Since the region contains both concentrated animal-feeding operations and a sizable human population, natural-resource managers are concerned about the diverse number of *E. coli* populations throughout the watershed. "There's only so much a municipal water treatment plant can do," Ibekwe notes. "There are 11 water treatment plants that discharge into the middle Santa Ana River in our study area, and that discharge makes up 90 percent of the summer flow."

Sourcing Solutions

Ibekwe, California State Polytechnic University researcher Shelton Murinda, and North Carolina State University researcher Alexandria Graves spent more than a year collecting 450 water and sediment samples from 20 sites throughout the watershed. The sites included urban areas, agricultural areas, parks, national forest lands—which provided information about bacterial contributions from wildlife and other background sources in undeveloped areas—and three wastewater treatment plants.

Then the scientists extracted *E. coli* bacteria from each sample and used pulsed-field gel electrophoresis (PFGE) to find distinctive segments of the organism's DNA that could be used to assign isolates to different groups. These DNA patterns, called "fingerprints," are detected by separating bacterial DNA into tiny pieces, placing the pieces in a gel, and then sending electricity through the gel. The electrical current separates the DNA pieces according to size to create a banding pattern. This is the fingerprint of each isolate. The individuals can be sorted into different groups, called "clonal populations," based on their fingerprint similarities.

Using PFGE, the researchers identified 600 different isolates of *E. coli* in their samples, many of which could be placed into 6 clonal populations. They found the greatest variety of different types of *E. coli* in runoff discharged from areas dominated by urban development or human activities.

"I think this is our most important finding—that *E. coli* populations in urban runoff are more genetically diverse than *E. coli* populations in agricultural runoff," Ibekwe says.

Ibekwe and colleagues also found that *E. coli* isolates collected from water and sediment samples at the same location and at the same time nevertheless exhibited a considerable level of genetic diversity. In addition, water samples often contained a more diverse assortment of *E. coli* isolates than sediment samples. This suggests that the *E. coli* found in sediment samples could belong to permanent population reservoirs, not transient populations that fluctuate along with discharge into the water channel.

A Range of Resistance

As part of the study, Ibekwe also tested all the *E. coli* isolates for their resistance to various antibiotics: rifampicin, tetracycline, erythromycin, cephalothin, streptomycin, ampicillin, and amoxicillin clavulanate. He found that between 88 to 95 percent of the isolates were resistant to rifampicin and that around 75 percent were resistant to tetracycline, an antibiotic commonly used to treat a range of infections in humans.

Tetracycline resistance was by far the most common type of resistance observed in *E. coli* isolates collected near wastewater treatment plants. The scientists also found that 24 percent of *E. coli* collected in sediment samples associated with urban runoff—a total of 144 isolates—showed resistance to as many as 7 antibiotics. The antibiotics associated with most multiple resistances were rifampicin, tetracycline, and erythromycin, and the 5 isolates with the highest multiple antibiotic resistance were found in streambed sediments collected from areas that receive urban runoff.

Finally, Ibekwe was surprised when they found 53 *E. coli* isolates that, based on DNA fingerprinting, they could not assign to any of the 6 clonal groups. But like the other isolates, these 53 outliers showed a range of resistance to several antibiotics.

The sheer range of different antibiotic-resistant *E. coli* isolates identified by Ibekwe and his colleagues suggests that public-health officials who track water quality might need to increase their database of *E. coli* fingerprints. "If we want to use PFGE for source tracking in a large watershed like the Santa Ana River, a very extensive DNA fingerprint library is needed, because our study shows that even a minor change in the DNA fingerprint can significantly affect clonal groupings," Ibekwe explains. "The fingerprint library will have to include isolates from potential multiple-contaminant sources and isolates that vary over time and space throughout the watershed. This will help in correctly identifying isolates that are a health concern."—By **Ann Perry,** ARS.

This research is part of Agricultural and Industrial Byproducts (#214) and Food Safety (#108), two ARS national programs described at www.nps.ars.usda.gov.

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Technician Damon Baptista (left) and microbiologist Mark Ibekwe collect a water sample from a creek that drains into the middle Santa Ana River Watershed. They are studying how the thousands of surrounding dairies affect the creek's water quality.

PEGGY GREB (D2687-1)

Livestock Waste Management 2.0

Recycling Ammonia Emissions as Fertilizer

One of the costs of running a farm can include buying nitrogen in the form of anhydrous ammonia to fertilize crops. But there are other agricultural costs associated with nitrogen, especially when the nitrogen in livestock waste produces pungent—and potentially harmful—ammonia emissions.

But on June 20, 2011, Agricultural Research Service soil scientists Matias Vanotti and Ariel Szogi filed U.S. Patent Application #13/164,363 for an invention that could help change on-farm nitrogen management. It's a system that uses gas-permeable membranes to capture and recycle ammonia from livestock wastewater before the ammonia goes into the air. The two scientists, who work at the ARS Coastal Plains Soil, Water, and Plant Research Center in Florence, South Carolina, found that they could use these membranes to reduce ammonia emissions from livestock waste and capture concentrated liquid nitrogen that could be sold as fertilizer.

The membranes are similar to materials already used in waterproof outdoor gear and in biomedical devices that add oxygen and remove carbon dioxide from blood. Using these materials, the scientists recorded an average removal rate of 45 to 153 milligrams (mg) of ammonia per liter per day when manure ammonia concentrations ranged from 138 to 302 mg ammonia per liter.

When manure pH increased, ammonia recovery also increased. For instance, the scientists were able to recover around 1.2 percent of the total ammonia emissions per hour from manure with a pH of 8.3. But the recovery rate increased 10 times—to 13 percent per hour—when the pH was 10.0.

In a follow-up study, Vanotti and Szogi immersed the membrane module into liquid manure that had 1,290 mg of ammonia per liter. After 9 days, the total ammonia concentration decreased about 50 percent to 663 mg per liter, and the pH decreased from 8.1 to 7.0. This meant that the gaseous, or free, ammonia in the liquid—the portion of the total ammonia linked to ammonia emissions—decreased 95 percent from 114.2 to 5.4 mg per liter. Using the same process in 10 consecutive batches of raw swine manure, they recovered concentrated nitrogen in a clear solution that contained 53,000 mg of ammonia per liter.

"When we started this research more than 10 years ago, the membranes were very expensive," Vanotti says. "But the prices have come down, so its use for recovering the ammonia in manure is now much more cost effective."

The scientists want to scale up the process to see whether the membrane modules would lower ammonia emissions when installed in manure pits below the slotted floors in swine barns or in manure tanks and lagoons. If so, they believe that livestock producers could use the technology to help meet air-quality regulations, save fuel, protect the health of livestock and their human caretakers, improve livestock productivity, and recover nitrogen that can be sold as fertilizer.—By **Ann Perry,** ARS.

This research is part of Agricultural and Industrial Byproducts, an ARS national program (#214) described at www.nps.ars.usda.gov.

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

Ammonia emissions from livestock waste can be more than a nuisance—they can harm animal health. But ARS scientists have shown that gas-permeable membranes can remove and concentrate the ammonia for eventual sale as fertilizer.

REGIS LEFEBURE (K5657-3)

Eco-Based Fire Logs
An Environmentally Friendly Invention From ARS

Artificial logs that create a cheerful and welcoming winter blaze in your fireplace might someday be made from a perhaps surprising source: grass clippings.

Mowing front and backyard lawns, plus fields at parks, schools, and other city and suburban landscapes, "creates tons of clippings that typically end up in landfills," says Agricultural Research Service chemist Syed H. Imam. "This raw material is abundant, ubiquitous, and available free of charge from many landfills that need to free up more space for other waste."

In tests conducted at the ARS Western Regional Research Center in Albany, California, near San Francisco, Imam and colleagues have shown that lawn clippings can be mixed with other natural compounds to yield eco-friendly fire logs that burn brightly and evenly. The same formula can also be used to produce pellets ready for the hopper of your pellet-burning stove or fire-starting sticks for using with firewood at a campfire.

Unlike many products manufactured today for burning in your fireplace, pellet stove, or campfire, the bio-based fire logs that Imam's team developed contain no petroleum-derived chemicals. That means the eco-logs burn cleaner, emitting fewer potentially polluting volatile organic compounds, or VOCs, Imam says.

Clippings make up about 20 to 60 percent of the composition of the logs, by weight. About 40 to 80 percent is made up of any of a number of plant-derived waxes or oils, referred to as "binders." They add durability and help the logs, pellets, or sticks retain their shape. Binders also boost the energy value of the log and extend its burn time.

All of the binders that Imam's team worked with, including rice wax and soy wax, are for the most part, commonly available, he notes.

Adding a small amount of a mineral oxidizer—up to 2 percent by weight—helps the logs ignite quickly and keeps the color and height of the flames consistent. Imam's group chose potassium chlorate for this purpose.

Though the Albany team's focus was on grass clippings, the logs can also be made from agricultural-harvest leftovers, such as rice straw, corncobs, or cornstalk residue. Manufacturing some other kinds of bio-based fire logs requires high temperatures. That's not the case with the logs from Imam's team.

"The grass clippings or other plant materials need to be dried to a moisture content of 15 percent or less," Imam says, "and the wax needs to be softened so that it will be evenly distributed throughout the log." This can be accomplished at relatively low temperatures (40˚ to 45˚C) in conjunction with shear forces created during the mixing and molding of the materials.

Imam and collaborators Roxana H. Imam, a former intern at the Albany center; and Jimmy C. Dorsey of New Venture Ideas, Inc., Pittsburg, California, are seeking a patent for their invention.—By **Marcia Wood,** ARS.

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

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Developed by ARS, this burning bio-based log is made of grass clippings and contains no petroleum-derived chemicals.

PEGGY GREB (D2698-1)

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