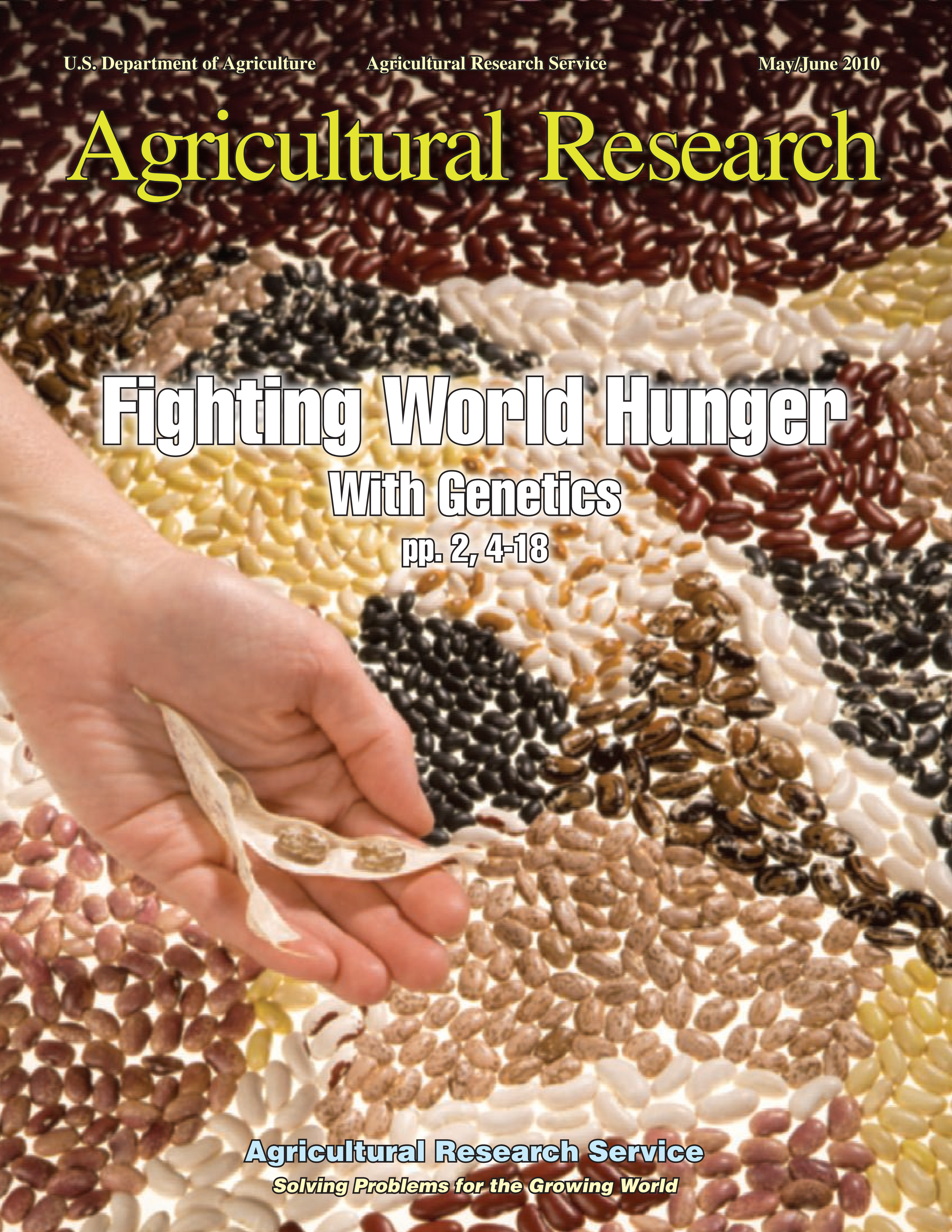
U.S. Department of Agriculture Agricultural Research Service May/June 2010

Agricultural Research



Fighting World Hunger With Genetics

pp. 2, 4-18

Agricultural Research Service

Solving Problems for the Growing World

FORUM

Using Genetic Tools To Combat Hunger

Walk into any grocery store and you will see it for yourself: We are producing an unprecedented bounty of food. Having such an abundant food supply begs the question: Why work so hard at improving our crops and livestock when we are already so successful? The answer is simple. We live in a changing world.

The world's population, now at 6.8 billion people, has more than doubled since the 1950s and is expected to reach 9 billion by 2050. The United Nations Food and Agriculture Organization predicts that food production will need to double by 2050 to meet the increased demand. Water supplies will also be a concern as the need to irrigate crops competes with demands from thirsty cities and suburbs in places as diverse as Beijing, New Delhi, and Phoenix.

Climate change is altering landscapes in ways we are only beginning to understand, affecting air temperatures, rainfall patterns, soil dynamics, and the seasonal cycles so vital for a bountiful harvest. Some experts predict that warmer temperatures will reduce yields and cause global food shortages.

New threats from pests and pathogens are also emerging. Ug99, a fungal pathogen, has become an international threat to wheat supplies since its discovery was reported in Uganda a decade ago. Sheath blight, considered the world's worst rice pathogen, has emerged as more of a danger since the 1970s, when scientists developed higher yielding rice varieties.

Chemical and agronomic solutions to pest, weed, and pathogen problems continue to evolve. Some research taps into the genetics and physiology of mosquitoes, ticks, and other pests to find environmentally sound treatments that will target specific arthropods by exploiting how they breathe, feed, shed cells, and reproduce.

When we talk about food supplies, we need to consider livestock health as well as human and crop health. For example, to subsistence farmers in sub-Saharan Africa and many other developing areas, bovine diseases can mean the difference between success and starvation by threatening just a few head of cattle.

To address these challenges, scientists are deciphering the DNA of our most important crops and livestock and tapping into genes that offer enhanced nutritional value, increased resistance to pests and diseases, and the ability to survive in changing climates. ARS researchers have been leading the way, unlocking genetic clues that have been instrumental in the development of beef and dairy cattle that are more productive and varieties of wheat, rice, corn, beans, and potatoes that are hardier and more nutritious.

You can read about some of these projects in this issue. For example, scientists in Stuttgart, Arkansas, are using DNA markers to identify rice varieties with genetic resistance to sheath blight. Other teams—in Beaumont, Texas, and New Orleans, Louisiana—are using rice genes to unlock nutrients in a new variety of high-fiber rice that may create a buzz with its distinct purple color.

Much of the research has an international reach. ARS scientists in Stoneville, Mississippi, are working with colleagues in Paraguay to identify genes that resist Asian soybean rust, a worldwide threat to soybeans. In Beltsville, Maryland, scientists are broadening the genetic base of beans to identify genes that resist the rusts that damage harvests in Africa and the Americas.

Another Beltsville team is working with farmers in Africa to breed hardier and more productive cattle by using technology developed by ARS scientists with help from international colleagues. The Illumina Bovine SNP50 BeadChip, a glass slide containing thousands of DNA markers, can identify useful genetic traits and has already proved to be a key tool in the United States for genotyping bulls that will sire offspring with desirable milk production traits.

To address the threat posed by Ug99, ARS researchers at several locations are collaborating with scientists in Kenya and at the International Maize and Wheat Improvement Center in Mexico to explore the genetics of both wheat and the pathogen.

In Aberdeen, Idaho, ARS scientists have produced potato varieties with increased protein and vitamin C content and are collaborating with Mexican scientists on field trials designed to find potatoes that resist late blight fungus, the pathogen that caused the Irish potato famine.

In some areas of sub-Saharan Africa, people get up to 60 percent of their calories from corn, which is very low in vitamin A. This diet can lead to vitamin A deficiencies that cause infant mortality, eye diseases, and blindness among children. ARS scientists in Ithaca, New York, discovered two varieties of corn that could increase vitamin A levels 15-fold. And researchers at the Children's Nutrition Research Center in Houston, Texas, have shown that Golden Rice-2, a variety 20 years in the making, will be effective at fighting vitamin A deficiencies.

We must grow our food smarter, with less water and on landscapes altered by climate change and threatened by evolving diseases and pests. ARS scientists are addressing that challenge, using genetics to develop crops and livestock that are more resilient and more nutritious. The work is a necessity not only for our health, but also for our survival in a changing world.

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

Steven M. Kappes
ARS Deputy Administrator
Animal Production and Protection
Beltsville, Maryland

May-June 2010
Vol. 58, No. 5
ISSN 0002-161X

Agricultural Research is published 10 times a year by the Agricultural Research Service, U.S. Department of Agriculture (USDA). The Secretary of Agriculture has determined that this periodical is necessary in the transaction of public business required by law.

Tom Vilsack, Secretary
U.S. Department of Agriculture

Vacant, Under Secretary
Research, Education, and Economics

Edward B. Knipling, Administrator
Agricultural Research Service

Sandy Miller Hays, Director
Information Staff

Editor: Robert Sowers (301) 504-1651
Associate Editor: Sue Kendall (301) 504-1623
Art Director: William Johnson (301) 504-1659
Photo Editor: Anita Daniels (301) 504-1609
Staff Photographers:
Peggy Greb (301) 504-1620
Stephen Ausmus (301) 504-1607

Paid subscriptions are available from the U.S. Government Printing Office (Superintendent of Documents). See back cover for ordering information. Complimentary 1-year subscriptions are available directly from ARS to public libraries, schools, USDA employees, and the news media. Call (301) 504-1638 or e-mail armag@ars.usda.gov.

Agricultural Research

Solving Problems for the Growing World

Cover: Beans are one of the staple crops that feed people all over the world. This photo shows the diversity of dry beans, including pinto, great northern, black, and kidney. The Agricultural Research Service works to develop beans with resistance to various diseases. Story begins on page 8. Photo by Peggy Greb. (D502-1)

IN THE NEXT ISSUE

HEALTH THROUGH FOODS—Much of ARS's research is directed towards improving the nutrient content of the foods we eat. And there is increasing evidence—also from ARS research—of the wisdom of this tactic. Our human nutrition research program closely studies the links between nutrients and human health. The next issue of the magazine reports on some of these studies, namely on the influence of nutrients on bone health, dementia, vision, heart health, cancer, diabetes, and the immune system.

Rice Improving Rice, a Staple Crop Worldwide

Rice *(Oryza sativa)* is the main dietary staple for more than half the world's population. In 2008, worldwide rice consumption exceeded 430 million metric tons. But the world's continued rice supply is jeopardized by a myriad of factors, including diseases and inability to keep up with demand.

Since the Agricultural Research Service is a world leader in rice research, it's no surprise that scientists at the Dale Bumpers National Rice Research Center in Stuttgart, Arkansas, and the Rice Research Unit in Beaumont, Texas, are involved in domestic and international efforts to improve rice varieties worldwide.

Giving Sheath Blight the Genetic Shove

As part of a multi-state and multi-institutional project called "RiceCAP," supported by the USDA National Institute of Food and Agriculture, geneticists Anna McClung and Georgia Eizenga and plant molecular pathologist Yulin Jia, at Stuttgart, and geneticist Shannon Pinson, at Beaumont, are working to pinpoint the exact genes that confer resistance to sheath blight. The disease is caused by *Rhizoctonia solani,* a fungus that can stay in the soil for 20 years, killing the plant's cells each planting cycle and affecting yield and grain quality.

The researchers had a breakthrough in their sheath blight mapping efforts when they identified and confirmed that a particular region on a chromosome—known as "quantitative trait loci *qShB9-2"*—has a major effect on controlling the disease.

"This is our most important discovery thus far on this project," says Jia. "It's the first time we have found—and are confident in—a chromosomal region with genetic resistance to this pathogen. It will now be easier to develop resistant rice varieties."

In a related project, Eizenga and colleagues screened wild rice species for signs of sheath blight resistance. Of the 73 wild species obtained from the International Rice Research Institute (IRRI) in the Philippines, 7 accessions showed the most resistance. The scientists have crossed some of these accessions with U.S. varieties lacking resistance, hoping to transfer resistance genes from these wild species to cultivated rice to create new germplasm. The researchers are currently working on mapping populations to identify the exact locations of these resistance genes.

The Stuttgart group has also developed a standardized greenhouse-screening technique for accurate phenotyping of sheath blight. In this technique, called the "microchamber method," 2-liter or 3-liter soft drink bottles are used to create a humidity chamber to promote disease development, allowing the scientists to measure the rice seedlings' disease reaction in just 7 days. This has accelerated the overall process of identifying novel, resistant resources from cultivated and wild relatives of rice. The technology has since been transferred to several rice-research programs in Latin America to help countries evaluate their rice varieties for sheath blight and other rice diseases.

Meanwhile, in Beaumont, Pinson and colleagues have been studying gene-mapping populations developed from recombinant inbred lines (RILs) of Lemont, a domestic cultivar, and TeQing, a cultivar from China. Because each of these lines contains different combinations of DNA, they can be used efficiently to find chromosomal regions containing genes for resistance to sheath blight. Pinson has been

PEGGY GREB (D1768-1)

Technician Piper Roberts (left) and geneticist Shannon Pinson look for disease symptoms after inoculation at the sheath blight disease nursery at Beaumont, Texas.

PEGGY GREB (D1769-1)

A rice leaf exhibiting typical watermark lesions associated with sheath blight disease.

PEGGY GREB (D1760-1)

In a Stuttgart, Arkansas, rice field, ARS plant molecular pathologist Yulin Jia (left) evaluates sheath blight disease in a mapping population with his assistant Guangjie Liu, of the University of Arkansas.

able to find 18 chromosomal regions with genes that help plants resist damage from the disease. Two of those chromosomal regions have shown a large, measureable effect on sheath blight resistance and were associated with flowering time and plant height.

The Lemont/TeQing RIL gene-mapping population is uniquely important in that it has two high-yielding cultivars as parents, is the first to be well adapted to the southern United States and other semitropical growing conditions, and contains more progeny lines than other rice gene-mapping populations, which makes estimation of genetic marker locations more precise and evaluations of marker-linkages easier for breeders.

Pinson has also teamed up with a scientist in the Philippines to develop a second gene-mapping population known as the "TeQing-into-Lemont introgression lines" (TILs), which consist of 123 genetic lines that each contain just 1 to 5 small pieces of TeQing DNA placed within a predominantly Lemont genetic background. This consistent genetic background surrounding the foreign TeQing genes allows researchers to more accurately measure the effect of each small piece of TeQing DNA. By looking at the trait expression of the TILs compared with each other and with pure Lemont plants, scientists can find genes having a small but significant impact and can determine their genomic location more precisely, which could help researchers improve worldwide rice production.

Taking the Bang Out of Rice Blast

Rice blast, caused by the fungus *Magnaporthe oryzae,* is a disease threatening rice worldwide. The fungus is airborne but is also transmitted through seed, infecting rice plants during all developmental stages. Strains of rice blast are always changing, making it a challenge to continually produce varieties resistant to it.

But McClung, Jia, fellow geneticist Bob Fjellstrom, and colleagues have made a breakthrough in understanding the disease. The scientists have developed molecular markers to screen for resistance genes. They have also found the *Pi-ta* gene gives rice resistance to several races of rice blast.

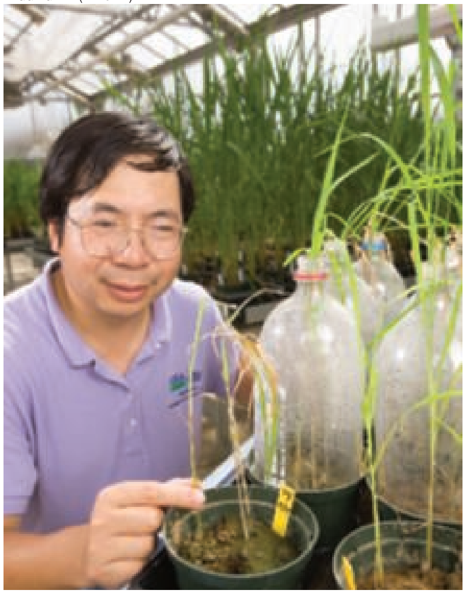
"For a long time, scientists believed that one gene only produces one protein to prevent infection by one race of the blast fungus," says Jia. "Our studies show that one gene may produce multiple proteins. *Pi-ta* can make 12 proteins, each capable of conferring resistance to up to 10 races. We have identified those races, giving breeders valuable information to use when selecting parents of new cultivars."

Recently, rice blast race IE-1k—a race to which *Pi-ta* doesn't confer resistance—appeared in rice paddies in the southern United States. Jia and colleagues found genes *Pi42(t)* and *Pi43(t),* from the Chinese cultivar Zhe733, confer resistance not only to IE-1k, but also to all common races of rice blast found in the United States. According to Jia, breeders can overlap *Pi-ta, Pi42(t),* and *Pi43(t)* to increase cultivars' longevity of resistance to rice blast.

Standardized Amylose Testing Improves Rice

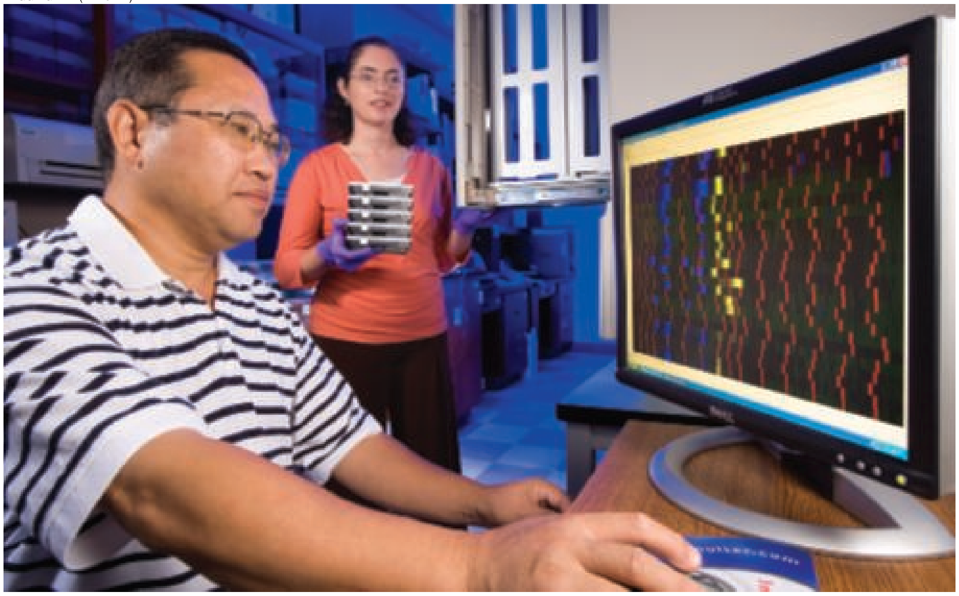
In addition to increasing yield and disease resistance, rice breeders try to ensure that the amylose content of a cultivar fits into a range that will provide a certain level of cooking quality. Starch amylose content is the key factor affecting the texture and processing properties of rice.

PEGGY GREB (D1762-1)



Using the microchamber method, Yulin Jia evaluates sheath blight disease of rice seedlings a week after inoculation with the fungus *Rhizoctonia solani.*

PEGGY GREB (D1761-1)



Geneticist Melissa Jia loads plates containing DNA from a sheath blight mapping population into an automated genotyping system while Guangjie Liu, of the University of Arkansas, analyzes the output to identify genes associated with sheath blight resistance.

And recent studies have correlated amylose content to “resistant starch”—which, after consumption, resists digestion in the small intestine. Resistant starch has been proposed to have health benefits similar to those of dietary fiber.

Amylose levels help rice breeders decide how best to market a rice variety. The amylose content typical of U.S. long-grain rice ranges from 19 to 23 percent, giving it a dry, fluffy texture after cooking. The typical U.S. medium-grain rice, which has an amylose content of less than 19 percent, is soft and sticky after cooking. Rice with an amylose content higher than 23 percent is used for canning.

“When rice breeders ask about the grain quality traits of a possible new rice germplasm source, amylose content is one of the traits that is looked at carefully,” says Beaumont chemist Ming-Hsuan Chen.

But there is a problem: The reported amylose content might not actually be the amount that the breeder is looking for. This is because the test to determine amylose content is not standardized worldwide, so test results vary from country to country—even for the exact same variety. For example, in 2009 the rice cultivars Kyeema and Doongara were reported to have amylose contents of 14 and 22 percent, respectively, in one country, 19 and 24 percent in another, and 20 and 28 percent in yet another.

“Such differences make it particularly difficult to exchange germplasm between breeding programs, present data to international audiences, or make associations between amylose values and traits or genotypes,” says Chen.

Each year, thousands of rice samples are analyzed at the Beaumont laboratory

A diseased rice leaf 1 week after inoculation with the rice blast fungus *Magnaporthe oryzae* under greenhouse conditions at Dale Bumpers National Rice Research Center, Stuttgart, Arkansas.

PEGGY GREB (D1764-1)

Golden Rice-2 Shines in Nutrition Study

All across America, rice has a loyal following among those who enjoy crispy rice cereal at breakfast, steamed white rice with a favorite entree at lunch, or a classic rice pudding as an evening dessert.

But America’s consumption of rice—about 21 pounds per person each year—is substantially less than that of people who live in the world’s “rice-eating regions,” mainly Asia, most of Latin America, and much of Africa.

Because vitamin A deficiency—and its harmful impacts on health—is common in some of these overseas areas, scientists in Europe and the United States have worked for more than a decade to genetically engineer white rice so that it will provide beta-carotene. Our bodies convert beta-carotene into retinol, a form of vitamin A.

White rice typically does not have any detectable beta-carotene. But the genetically engineered Golden Rice-2 from Syngenta Corporation does. Until now, however, scientists haven’t known how efficiently our bodies can convert the beta-carotene in Golden Rice-2 into retinol.

Research published in a 2009 issue of the *American Journal of Clinical Nutrition* provides a scientifically sound answer. Agricultural Research Service plant physiologist Michael A. Grusak, carotenoids researcher Guangwen Tang, and colleagues reported, for the first time, their findings that one 8-ounce cup of cooked Golden Rice-2 provides about 450 micrograms of retinol. That’s 50 to 60 percent of the adult Recommended Dietary Allowance of vitamin A.

Tang, who led the study, is at the ARS Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University, Boston, Massachusetts; Grusak is with the ARS Children’s Nutrition Research Center at Baylor College of Medicine in Houston, Texas.

ARS, the National Institutes of Health, and the U.S. Agency for International Development funded the research.

The scientists based their determinations on tests with five healthy adult volunteers who ate one serving of the rice at the start of the 36-day study. Volunteers’ blood was sampled at more than 30 intervals during the research. By analyzing those samples, the researchers were able to determine the amount of beta-carotene (and retinol) that the volunteers absorbed (and then converted to retinol) from the Golden Rice-2.

The efficient conversion of Golden Rice-2 beta-carotene into vitamin A strongly suggests that, with further testing, this special rice might help reduce the incidence of preventable for amylose content and other critical end-use quality traits. The scientists there have standardized their method of determining amylose content so that the values are repeatable year after year.

Chen has joined the International Network for Quality Rice and collaborates on a project led by IRRI's Melissa Fitzgerald and commissioned by the International Union of Pure and Applied Chemistry. The goal of this project is, through worldwide collaboration among rice quality labs, to establish a standardized test for amylose content determination internationally.

Continued Collaboration Vital to Success

"The exchange of plant germplasm and genetic stocks helps to identify genes and genetic markers that can be used by rice breeders globally to develop new cultivars that will sustain agriculture and help feed the world," says McClung, research leader of both the Stuttgart and Beaumont laboratories.

Scientists in Stuttgart received several wild rice species collected from rice-growing regions around the world and stored at IRRI to help identify novel disease-resistance genes. In return, Stuttgart scientists sent IRRI about 400 purified rice cultivars representative of rice grown around the world, which can be used to identify markers associated with traits important to rice production practices in Asia.

Additionally, ARS, the University of Arkansas, and IRRI have an ongoing informal collaboration to identify genes and plant traits that will contribute to the development of high-yielding rice cultivars with disease resistance. In another project, ARS is working with IRRI and Cornell University to develop 600,000 genetic markers that can be used to identify genes that control yield, grain quality, and resistance to physiological stress, insects, and disease in rice cultivars from around the world.

Such work ensures that people worldwide will be able to enjoy rice for years to come.—By **Stephanie Yao** and **Alfredo Flores,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301) and Crop Protection and Quarantine (#304), two ARS national programs described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Stephanie Yao, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1619, stephanie.yao@ars.usda.gov. ✷

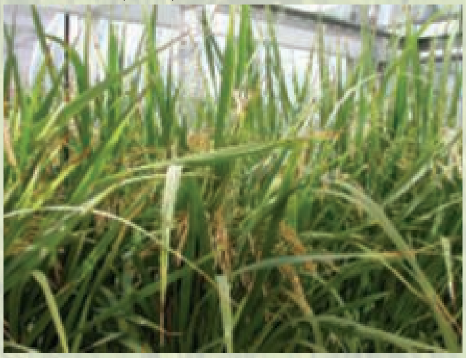
night blindness and other effects of vitamin A deficiency in rice-eating regions. Right now, more than 200 million people around the globe don't get enough vitamin A.

Grusak conducted experiments that made it possible for Tang's group to detect beta-carotene (and resultant retinol) derived from Golden Rice-2, differentiating it from beta-carotene or retinol from other sources.

In his experiments, Grusak determined how to get Golden Rice-2 plants, grown in his rooftop greenhouse at Houston, to take up a harmless tracer and incorporate it into the beta-carotene in the developing grains. The tracer, a rare yet safe and natural form of hydrogen, can be detected by a gas chromatograph-mass spectrometer, the kind of instrument that Tang's team in Boston used to analyze volunteers' blood samples.

The tracer, deuterium oxide, is not new to vitamin A research. But Grusak's studies are the first to show how the tracer can be successfully incorporated into the grains of a living plant for vitamin A investigations.

MICHAEL A. GRUSAK (D1789-1)



Golden Rice-2 plants growing in a greenhouse.

"It was tricky to determine how much tracer to use and when to add it to the nutrient solution we grew the plants in," says Grusak. His method might be used in other pioneering research geared to boosting the nutritional value of other grains worldwide.—By **Marcia Wood,** ARS.

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

Michael A. Grusak is with the USDA-ARS Children's Nutrition Research Center at Baylor College of Medicine, 1100 Bates St., Houston, TX 77030, (713) 798-7044, mike.grusak@ars.usda.gov.

Guangwen Tang is with the ARS Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University, 711 Washington St., Boston, MA 02111, (617) 556-3236, guangwen.tang@tufts.edu. ✷

Beans
Help for the Common Bean: Genetic Solutions for Legume Problems

The common bean—which includes pinto, great northern, navy, black, kidney, and snap beans—is considered by many nutritionists to be a nearly perfect food because of its high protein content and low cost. But it is also susceptible to many diseases that reduce seed and pod quality and yields. Agricultural Research Service scientists from labs across the United States are playing major roles in finding solutions to what ails these legumes.

Beltsville Beans Key to Combating Devastating Rust Pathogen

ARS plant pathologist Talo Pastor-Corrales, throughout his career, has traveled to 21 countries in the Americas and 11 in Africa studying bean diseases and searching for bean varieties that contain special traits—particularly disease resistance—that could be used to improve common beans. In the Soybean Genomics and Improvement Research Unit in Beltsville, Maryland, Pastor-Corrales specializes in genetic resistance of the common bean *(Phaseolus vulgaris)* to various diseases.

He's also the lead scientist in a project that aims to discover and breed genes into *P. vulgaris* for resistance to common bean rust and the newly arrived Asian soybean rust pathogen, which also infects the common bean.

The fungus that causes bean rust is very aggressive and exists as many different strains called "races." Pastor-Corrales says, "When new races appear, they can infect bean varieties that were previously resistant to rust." Further complicating matters is the fact that races present in a field can vary from one year to another.

Of major concern is the loss of effectiveness of the *Ur-3* rust-resistance gene in beans, which has been very effective in controlling bean rust in the United States, especially in North Dakota and Michigan, the two largest producers of dry beans in the United States. In recent years, however, rust has developed on these once-rust-resistant bean varieties, and there is concern that the new races will spread to other Northern Plains states, such as Colorado and Nebraska.

In 2008 and 2009, Pastor-Corrales and his project team were credited with developing new dry bean cultivars resistant to the rust pathogen. Pastor-Corrales collaborated with scientists from the University of Nebraska and Colorado State University. The new cultivars contain two or more rust-resistance genes and most also have the *Ur-11* gene, considered the most effective rust-resistance gene in the world.

PEGGY GREB (D1791-1)

Plant pathologist Talo Pastor-Corrales examines a bean cultivar that is a new source of genes for resistance to a hyper-virulent pathogen that causes rust disease of dry and snap beans.

Beans That Can Take the Heat

At test plots in southern Puerto Rico, ARS plant geneticist Tim Porch's beans are feeling the heat. As part of collaborative breeding efforts with Cornell University, the University of Nebraska, and the University of Puerto Rico, Porch and colleagues have been testing new bean germplasm for heat and drought tolerance and disease resistance. So far, their efforts have proved fruitful.

Porch is in the process of releasing two new kidney bean varieties with heat tolerance. These germplasm releases, named "TARS HT-1" and "TARS HT-2," were initiated by ARS plant geneticist Rusty Smith, now with the ARS laboratory in Stoneville, Mississippi. TARS HT-1 does well under the stress of high day and high night temperatures, whereas TARS HT-2 does well under the stress of high day and moderate night temperatures.

Also in the works is new black bean germplasm with heat and drought tolerance and resistance to common bacterial blight, a seedborne disease—spread by splashed water—that mainly attacks the plant's leaves and pods. Porch crossed tropical black and red beans to produce these germplasm lines, which are adapted to temperate areas and will help to increase the diversity of U.S. bean germplasm. Field tests in Nebraska show that the lines yield well in addition to having tolerance to heat, drought, and disease.

"The beans we are testing have broad adaptation," says Porch, who is with ARS's Tropical Agriculture Research Station (TARS) in Mayagüez, Puerto Rico. "Our lines do well in the short days common to Puerto Rico and the long days found in Nebraska." Porch is testing other bean types—red, pinto, great northern, and navy—that are drought tolerant, and some also have heat tolerance and disease resistance. "My goal is to pyramid multiple resistances to generate lines with broad adaptation and genetic diversity."

Porch is also involved in bean-improvement efforts in Angola, a country that is beginning to recover from many years of civil war. The project, funded by USAID and led by the University of Puerto Rico, supports Angola's common bean breeding program. Porch and university colleagues conduct breeding and pathology training sessions, host Angolan scientists to train them in the laboratory, and help the scientists breed for traits of importance, such as resistance to angular leaf spot, common bacterial blight, and bean common mosaic virus.

PEGGY GREB (D957-1)

Geneticist Tim Porch examines the effects of high-temperature stress on pod development in the common bean.

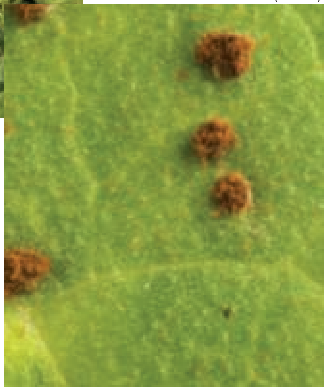
Washington's Wonders

At ARS's Vegetable and Forage Crops Research Laboratory in Prosser, Washington, plant pathologist Richard Larsen and geneticist Phil Miklas recently identified new sources of resistance for protecting snap beans from the viral disease chocolate pod, which was first detected in Wisconsin, Michigan, and other Great Lakes states in 2001 and inflicts unsightly defects on pods, ruining their marketability.

Insecticides are sometimes used to kill virus-transmitting aphids. But incorporating resistance into snap beans is considered a more sustainable approach. Toward that end, the researchers devised DNA marker technology to help speed identification and use of plants harboring chocolate pod resistance without having to grow them to maturity.

Reducing insecticide use—and safeguarding the environment—was also the goal of a project that entomologist Stephen Clement recently completed at ARS's Plant Germplasm Introduction and Testing Research Unit in Pullman, Washington. There, as part of a 3-year project supported by the U.S. Agency for International Development, Clement led development of chickpea germplasm lines offering beet armyworm resistance. The moth's caterpillar stage attacks many crops, but is especially problematic in chickpeas in India, which produced 6.6 billion tons of the high-fiber, vitamin-rich crop in 2005.

PEGGY GREB (D508-1)



Close-up of pustules (fungal fruiting structures containing thousands of spores) of bean rust fungus on a susceptible bean leaf.

Clement collaborated on the project with scientists at Washington State University-Pullman and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru, India. In U.S. trials, 28 to 62 percent of beet armyworms that fed on the leaves of resistant chickpeas died within a few days. Those that survived were smaller and shorter than usual. Now, ICRISAT entomologist Hari Sharma is conducting field trials to evaluate the resistant chickpeas' potential to forestall insecticide use.

Earlier this year, George Vandemark, a geneticist at ARS's Grain Legume Genetics and Physiology Research Unit, also in Pullman, released a new Eston class lentil named "Essex." This new variety was developed through a collaborative effort involving Vandemark, Fred Muehlbauer (now retired from

STEVE CLEMENT (D1787-1)

Entomologist Hari Sharma, ICRISAT, and a colleague in a chickpea research plot at the Regional Research Station, Kukumseri, in the Himalayan foothills of northern India.

ARS), and North Dakota State University pulse crop breeder Kevin McPhee.

They chose Essex for release because of its outstanding performance in yield trials conducted in Washington State, Idaho, North Dakota, and Montana—states that produced a combined $87 million's worth of lentils, most of it for export.

On average, Essex yielded 1,220 pounds of seed per acre—21 percent more than Eston and 22 percent more than Athena, commercial varieties used for comparison. Essex is intended for production in the Northern Plains, with Mexico and other Latin American nations as prime export destinations.—By **Alfredo Flores, Stephanie Yao,** and **Jan Suszkiw,** ARS.

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

To reach the scientists mentioned in this article, contact Alfredo Flores, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1627, alfredo.flores@ars.usda.gov. ✷

GEORGE VANDEMARK (D1795-1)

Essex lentils. The average diameter is 7 millimeters.

STEPHEN AUSMUS (K10344-1)

Geneticist Phil Miklas compares susceptible (left) and resistant (right) bean lines exposed to virus infection.

Better Beans Mean Better Health *for People Everywhere*

Whether it's a side of beans for a hearty breakfast, an extra-spicy chili at lunch, or an elegant, chilled black bean soup at dinner, beans can add pleasing color and texture to any meal. And, importantly, beans provide iron, an essential nutrient needed in comparatively small, or "micro," amounts.

In Ithaca, New York, ARS physiologist Raymond P. Glahn, ARS research associate Elad Tako, Cornell University analytical chemist Michael A. Rutzke, and others conduct research that may help plant breeders develop new and improved beans that are even better sources of iron. Their research would especially benefit the more-than-2-billion people around the globe who are deficient in iron. Iron deficiency is, in fact, the world's number-one micronutrient deficiency.

Some of these investigations are designed to determine how to boost beans' iron bioavailability—the amount of iron our bodies can absorb and use from beans. That might be done in a number of ways, all using plant breeding. One way, of course, would be to increase the level of iron in these legumes. Another approach would be to increase the effects of certain natural compounds that enhance iron bioavailability. A third tactic: decrease the effects of natural compounds that make iron less absorbable.

To discover more about the availability of iron in beans—or in other foods and food components—Glahn developed a laboratory test in 1998 that uses Caco-2 (pronounced KAY-coe) human intestinal cells to give an indication of how our digestive system would treat beans and nutrients from beans.

Glahn says follow-up tests with lab animals "are an important intermediate step between the Caco-2 tests and costly studies with human volunteers." In recent years, Glahn and coresearchers at the ARS Robert W. Holley Center for Agriculture and Health, on the Cornell University campus at Ithaca, have shown that chickens "have promise as an animal model for iron absorption studies."

In research published this year in the journal *Poultry Science,* the scientists report that chickens are sensitive to iron deficiency and that at least a half-dozen different indicators of this deficiency, used in studies with other animals, are also valid for research with chickens.

The team's tests with chickens confirmed their Caco-2 findings, namely, that iron in red beans was less bioavailable to the animals than iron in white beans.

Notes Glahn, "This is the first time this disparity in bean-iron bioavailability has been shown in an animal study. It has implications for human nutrition."

The investigation underscores the contribution that findings from Caco-2 and poultry-based assays might have in helping reverse iron deficiency worldwide.—By Marcia Wood, ARS.

Wheat ARS Wheat Rust Resistance Roundup

The stem rust fungus *Puccinia graminis* has long plagued the world's wheat, barley, and other grain crops. But none of the fungus's main types have matched the devastation wrought by Ug99. It's a virulent new race that even stem rust-resistant varieties cannot withstand.

So pressing is the threat posed by Ug99, known scientifically as *"Puccinia graminis* f. sp. *tritici,"* that the Agricultural Research Service has committed multiple labs to the global fight against the pathogen. ARS's efforts also support the Borlaug Global Rust Initiative, an international effort to rush newly developed rust-resistant cultivars to affected wheat growers, whether they be in regions where Ug99 already occurs—namely, parts of North Africa and the Middle East—or areas it could spread to next.

The labs, followed by summaries of their Ug99 research, include:

Cereal Disease Laboratory, St. Paul, Minnesota—Characterizes and monitors Ug99 and other emerging rust strains; tests breeding germplasm of U.S. wheat and barley for resistance to Ug99 in the greenhouse; identifies new sources of resistance in cultivated and wild relatives of wheat; develops molecular markers; and creates genetic maps of Ug99 and other important rust strains. (See "World Wheat Supply Threatened!" *Agricultural Research,* November/December 2007, pp. 4-6.)

Plant Science Research Unit, Raleigh, North Carolina—Coordinates Ug99 screening of U.S. wheat and barley submissions at the Njoro Research Center of the Kenya Agricultural Research Institute; developed wheat lines with multiple genes for resistance to Ug99 and other stem rusts; and identified resistance sources in several barley lines being tested in Kenya. (See "International Wheat and Barley Screening Collaboration Helps Uncover Stem Rust-Resistant Material," *Agricultural Research,* February 2010, pp. 8-9.)

Small Grains and Potato Germplasm Research Unit, Aberdeen, Idaho—Coordinates acquisition and shipping of seed from wheat breeders across the United States for testing in Kenya; prescreens landrace wheats from the National Small Grains Collection against local stem rust races; and crosses resistant landraces tested in Kenya to study inheritance in offspring as part of the effort to discover new resistance genes. (See "International Wheat and Barley Screening Collaboration Helps Uncover Stem Rust-Resistant Material," *Agricultural Research,* February 2010, pp. 8-9.)

Cereal Crops Research Unit, Fargo, North Dakota—Identified novel sources of stem rust and Ug99 resistance in rye, goat grasses, perennial wheat grasses, and other wild species; and combined classical cytogenetics with molecular marker techniques to develop bread and durum wheat lines carrying resistance genes derived from wild relatives of wheat, including *Sr37, Sr39, Sr43,* and *Sr47,* that are free of "linkage drag"—unwanted segments of chromosome that can be inherited from wild species along with rust resistance genes, hindering commercial breeding efforts.

Hard Winter Wheat Genetics Research Unit, Manhattan, Kansas—Identified four new resistance genes from wild relatives of wheat to combat Ug99 and developed genetic stocks for their use in wheat breeding; developed genetic markers and improved germplasm for several Ug99-effective resistance genes, including *Sr22, Sr35,* and *Sr40;* used chromosome-engineering techniques to shorten introduced chromosome segments from wild relatives of wheat and thus reduce undesirable linked characters; and use marker-assisted selection to move useful resistance genes into elite hard winter wheat varieties for Central and Southern Plains breeders.—By **Jan Suszkiw,** ARS.

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

To reach scientists involved in these projects, contact Jan Suszkiw, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1630, jan.suszkiw@ars.usda.gov. ✷

YUE JIN (D1797-1)

Ug99-infected wheat from a nursery in Njoro, Kenya.

Corn

Boosting Vitamin A Levels in Corn To Fight Hunger

Corn is essential to the diets of hundreds of millions of people in developing countries, including those in sub-Saharan Africa. But millions of those people are at increased risk of health problems because their corn-based diets lack enough vitamin A. Some 40 million children are afflicted with xerophthalmia, an eye disease that can cause blindness, and 250 million people suffer health problems because of a lack of dietary vitamin A. Agricultural Research Service researchers and colleagues at Purdue University and the International Maize and Wheat Improvement Center (CIMMYT) have made some discoveries that could change that.

Research may triple corn's carotenoids.

Corn contains carotenoids, such as beta-carotene, that our bodies convert to vitamin A, but only a very small percentage of corn varieties have naturally high carotenoid levels. Using genetic and statistical tools, the researchers have identified two genes in corn that are linked to higher beta-carotene levels, and they have developed a cheaper and faster way to screen corn plants for more genes that will produce even higher levels of the essential nutrient. The research is expected to at least triple the levels of carotenoids in Africa's corn and could increase levels in some varieties far beyond that, according to Edward Buckler, a geneticist in ARS's Robert W. Holley Center for Agriculture and Health in Ithaca, New York.

The project, funded in part by the National Science Foundation, included major contributions from geneticist Marilyn Warburton of the ARS Corn Host Plant Resistance Research Unit in Starkville, Mississippi; Torbert Rocheford, a crop geneticist at Purdue University in West Lafayette, Indiana; and Jianbing Yan, from CIMMYT in Mexico.

Corn is one of the world's most genetically diverse food crops. Like people, each ear has a slightly different genetic makeup, resulting in slightly different characteristics. That poses a formidable challenge to scientists trying to understand the genetic basis for any corn nutrient. Direct nutrient-screening techniques are expensive. A common technique, high-performance liquid chromatography, can assess levels of beta-carotene in individual plant lines, but screening a single sample costs $50 to $75. Breeders need to screen hundreds—or more—of plants at a time, making the cost prohibitive. Genetic screening via molecular markers would be a more efficient option for screening large numbers of plants if genes involved in high beta-carotene levels were known. After identification of high-carotenoid corn lines, markers enable efficient transfer of the trait to many new varieties via marker-assisted selection; this is important because farmers in developing nations need high-carotenoid varieties that will grow over a wide range of climates and conditions.

A New Approach and a Better Way To Assay Corn

The team took a new approach to identify specific genes and regions of the corn chromosomes that influence production of carotenoids. They examined the corn genome through "association mapping," a method made possible by recent breakthroughs in statistical analysis and DNA sequencing, techniques that accelerate genetic profiling of crops. Association mapping taps the natural genetic diversity of corn to find new and useful traits.

In their study, the researchers surveyed the genetic sequences of diverse corn from around the world. They found two naturally mutated genes, each producing an enzyme at lower levels than those found in most corn varieties. Plants with either gene mutation have higher levels of beta-carotene, and plants with both mutations have higher levels still. Identification of the two genes using the new methods was an important breakthrough in nutritional plant breeding and has been published in the journals *Science* (2008) and *Nature Genetics* (2010).

After genes are identified via association mapping, markers can be developed from these genes to allow for marker-assisted selection, which is much simpler, faster, and "up to 1,000-fold cheaper" than running the types of chemical tests previously used, Buckler says.

Now, scientists in developing countries can cross the newly identified high beta-carotene lines with local varieties and, applying the markers developed from these two genes, choose progeny that are adapted to local growing conditions but still retain high beta-carotene.

Warburton, Yan, and Michael Gore, a former graduate student in Buckler's lab who is now an ARS geneticist at the U.S. Arid-Land Agricultural Research Center in Maricopa, Arizona, are working with various international organizations, such as CIMMYT, China Agriculture University, and the International Institute for Tropical Agriculture, to train plant breeders in developing countries to use their techniques. Some African maize has as little as 0.1 micrograms of beta-carotene per gram of corn. The researchers are confident they will eventually find genes that result in corn with 15 micrograms of beta-carotene per gram, a target for nutritional scientists around the globe working to improve corn varieties and fight world hunger.

"We see large variation in the corn genome, and that gives us a lot to work with," Warburton says.—By **Dennis O'Brien,** ARS.

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

To reach scientists mentioned in this article, contact Dennis O'Brien, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1624, dennis.obrien@ars.usda.gov. ✸

TOBERT ROCHEFORD (D1784-2)

Maize varies widely in carotenoid content, which affects the grains' color. The white kernels here have almost no carotenoids, while the orange ones are almost as high in them as carrots. But color does not necessarily indicate beta-carotene levels, so researchers look for beta-carotene differences at the gene level.

Potatoes

Nutrient-Packed and Pest-Resistant Potatoes From ARS Research

Potatoes are America's number one vegetable crop. Per capita, Americans consume about 130 pounds annually. Worldwide, it's the fourth largest crop after wheat, rice, and corn. But it's a wonder that the potato makes it to the dinner table at all, given the myriad pests and diseases that can take hold well before harvest.

There's the Columbia root-knot nematode, which costs U.S. growers $20 million annually; the potato tuber moth; and late blight, which caused the Irish Potato Famine of 1845 and is still responsible for significant losses and control expenses today. Chemical fumigants and fungicides have long been a staple defense for these pests and pathogens. But the onset of resistance in new pest or pathogen biotypes—coupled with environmental concerns about long-term pesticide use—has prompted the search for sustainable solutions in the form of genetic resistance.

A Recent Defender

Nationwide, ARS researchers are seeking to develop new potato varieties that will not only hold their own against insects and disease, but also maintain their storage quality and deliver nutrients that promote health and well-being in spud lovers the world over.

For example, at ARS's Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, geneticist Rich Novy

JEFF MILLER (D1790-1)

Green plants of the late blight-resistant potato variety Defender, surrounded by susceptible varieties killed by late blight in a test plot at Bonners Ferry, Idaho.

PEGGY GREB (K10166-1)

Geneticist Rich Novy harvests tubers of a potato breeding clone at Tetonia, Idaho.

and plant pathologist Jonathan Whitworth spearhead a program to develop new potato lines that are resistant to different biotypes of the late blight pathogen, *Phytophthora infestans.* Toward that end, they're collaborating with Héctor Lozoya-Saldaña, a potato researcher in Chapingo, Mexico, where late blight is endemic.

"We send 2,500 breeding clones annually to Chapingo, where Lozoya-Saldaña evaluates them for late blight resistance," says Novy. "We then have a duplicate planting of those same breeding clones at Aberdeen, where—based on his late-blight readings—we concurrently select resistant clones and advance them in our program," based on their agronomic performance under irrigated production in the western United States.

The late blight-resistant cultivar Defender is an example of a recent release (2006) from the program. Defender has helped growers save on fungicides and other expenses associated with controlling late blight, which attacks the crop's leaves and tubers, rendering the latter unmarketable. Over the next few years, Defender may be joined by one more blight-resistant potato variety, depending on how it performs in ongoing trials in Idaho, Oregon, Washington, California, and Texas.

Typically, potatoes evaluated by Novy and Whitworth—and released in collaboration with university colleagues and the grower-supported Potato Variety Management Institute—are selected for their likelihood of success in the western United States. But requests for such releases also originate from other regions of the country and from outside the United States, where some of the same problems occur.

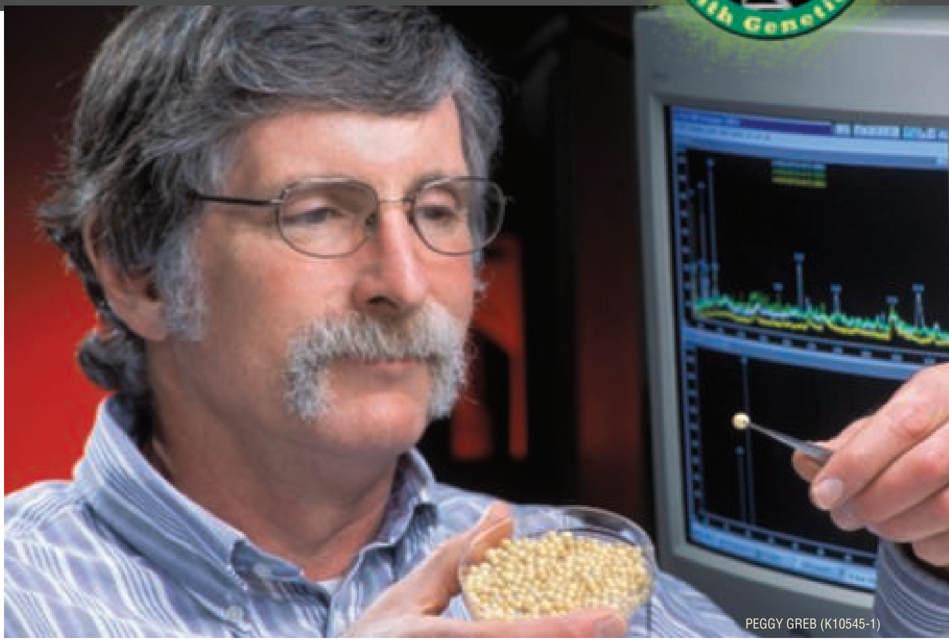
Saving Stored Spuds

Potato diseases are costly, but so are postharvest losses, which range from 10 to 30 percent of the harvested crop. Postharvest losses result mainly from early sprouting and infections caused by wounds suffered during harvest. Some potato varieties also lose nutritional and processing quality faster than others during extended storage.

"Most potatoes come from family farms that cannot afford to take such losses," says Jeff Suttle, research leader in the ARS Sugarbeet and Potato Research Unit at Fargo, North Dakota, and its work site at East Grand Forks.

Marty Glynn, Suttle's colleague at East Grand Forks, works closely with the Northern Plains Potato Growers Association and public potato breeding programs across the United States to evaluate the storage properties of promising new potato varieties. The evaluations are made using a 1/20-scale processing line that exactly mimics those used by large-scale commercial processors of potato chips and French fries. This collaboration has recently given rise to two named cultivars—Dakota Crisp and Dakota Diamond, which fare well even after 9 months of storage.

Seventy percent of all U.S. potatoes are processed into chips, French fries, and dehydrated flakes. Maintaining adequate potato storage quality for processing—in



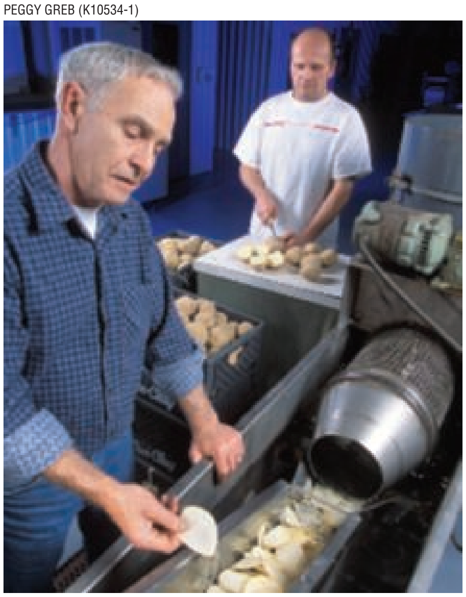
PEGGY GREB (K10545-1)

Physiologist Jeffrey Suttle inspects microtubers for signs of sprouting before hormone analysis by mass spectrometry.

some cases up to 10 months—is paramount to potato producers and processors.

Two priorities for storage managers are wound-healing and sprout control. Potatoes are wounded during harvest and must heal in order to prevent infection by other pathogens. Chemist Ed Lulai, with ARS in Fargo, has identified hormonal signals stimulating the healing process.

PEGGY GREB (K10534-1)



Pilot plant operator Dennis Olson (right) and food technologist Marty Glynn prepare slices of potatoes for frying and evaluation.

At harvest, potatoes are dormant. During storage, dormancy ends and sprout growth commences. Sprouting, in turn, results in numerous biochemical changes, which diminish the nutritional and processing qualities of potatoes. Postharvest sprouting is typically controlled during storage with chemical inhibitors. The long-term goal of Suttle's program is to find less costly, nonchemical solutions to the problem by identifying the genetic cause for early-sprouting tubers. The researchers have identified internal mechanisms that signal sprouts to grow, and they are currently isolating the genes responsible for these signals. Once identified, these genes can be used in potato breeding programs to modify the sprouting characteristics of any given potato line.

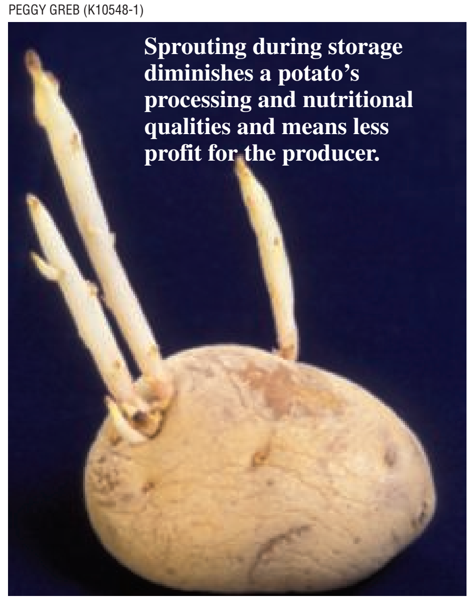
Improved nutrition is another objective: For example, at Aberdeen, the focus is on elevated protein and vitamin C content. Clearwater and Classic, both varieties released in 2008, boast 30 to 40 percent more protein than the Russet Burbank variety.

At ARS's Vegetable and Forage Crop Research Unit in Prosser, Washington, geneticists Chuck Brown and Roy Navarre are seeking increased antioxidant activity and elevated levels of phytochemicals.

Together with colleagues, they've devised new analytical methods for detecting and measuring phytochemical concentrations in tubers. Using these methods, they found a range of phenolic concentrations—from 100 to more than 1,500 milligrams per 100 grams dry weight—in both wild and cultivated potato lines. Phenolics may help diminish cardiovascular disease, respiratory problems, and certain cancers, the researchers say. One type, chlorogenic acid, is being tested by university cooperators for its potential to lower blood pressure. And, says Navarre, some of these potatoes have high levels of antioxidants (more than 300 micromoles Trolox equivalents per gram dry weight) that rival vegetables like spinach.

The data from Prosser shows the potential for developing high-phytonutrient potatoes. But without a reliable source of disease and/or pest resistance to protect them, such spuds would be less apt to deliver their health-promoting payloads to consumers worldwide. That's why Brown and colleagues have developed germplasm lines like PA99N82-4, a Russet potato that resists Columbia root-knot nematodes. These wormlike parasites cause unacceptable tuber defects, and fumigants are required to produce potatoes where the nematodes exist.

PEGGY GREB (K10548-1)



Sprouting during storage diminishes a potato's processing and nutritional qualities and means less profit for the producer.

Each growing region has its own unique combination of pest and pathogen problems or other peculiarities. Thankfully, ARS's potato research locations are strategically located to address them, typically in collaboration with state universities and affected industries. The result is an interconnected network that not only benefits the U.S. potato industry, but other nations as well. That's especially important given today's increasing global commerce and the unique challenges and opportunities it presents.—By **Jan Suszkiw** and **Alfredo Flores,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301), Plant Biological and Molecular Processes (#302), and Plant Diseases (#303), three ARS national programs described at www.nps.ars.usda.gov.

To reach scientists featured in this article, contact Jan Suszkiw, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1630, jan.suszkiw@ars.usda.gov. ✷

STEPHEN AUSMUS (D857-1)

Geneticists Chuck Brown (left) and Roy Navarre examine some of the diverse potato lines prior to analysis of phytonutrients.

STEPHEN AUSMUS (D1726-10)

Looking for signs of resistance, geneticists Dennis Halterman (left) and Shelley Jansky examine resistant (being held) and susceptible potato plants that have been inoculated with *Phytophthora infestans,* the causal agent of late blight.

Fighting Potato Diseases by Enhancing Germplasm

Geneticists Dennis Halterman and Shelley Jansky, with ARS's Vegetable Crops Research Unit in Madison, Wisconsin, are hunting for wild potatoes that contain resistance to important diseases plaguing potato growers nationwide.

One wild potato Halterman has identified, *Solanum verrucosum,* contains a gene with resistance to late blight. Efforts are under way to cross *S. verrucosum* with cultivated potato and integrate the late blight resistance gene.

The researchers are looking to produce germplasm useful for developing a potato cultivar with resistance to both late blight and early blight, which also affects tomatoes. Early blight, a fungal disease, mainly affects the potato plant's leaves and stems but, if left uncontrolled, can also reduce yield. To create the multi-disease-resistant cultivar, the scientists crossed *S. verrucosum* with another wild potato species that has resistance to early blight, and then crossed the resulting wild potato hybrid with cultivated potato. They currently have seedlings in the greenhouse waiting to be field tested.

Halterman and Jansky are also looking for resistance to *Verticillium* wilt, another fungal disease that can remain in the soil for up to 10 years. Halterman developed a molecular marker to screen germplasm for resistance to this disease, saving the scientists time and effort. They found resistance in the wild potato species *S. chacoense* and produced cultivated potato hybrids that contain the important gene. According to Halterman, this is a good, durable gene that should hold up in the long term.

The scientists are also targeting the potato diseases potato virus Y and common scab.—By **Stephanie Yao,** ARS.

Selections From the National Agricultural Library

A burgeoning array of websites, books, scientific research articles, and other print and electronic sources provide facts, figures, and perspectives on the global fight to end world hunger. Reference librarian Felecia Tyler of the Agricultural Research Service's National Agricultural Library in Beltsville, Maryland, and Washington, D.C., offers these recommendations for viewing, listening, and blogging.

Feeding Minds, Fighting Hunger: A World Without Hunger
www.feedingminds.org

Describing itself as an "international classroom for exploring the problems of hunger, malnutrition, and food insecurity," this multilingual, kid-friendly site from the American Federation of Teachers and 10 humanitarian organizations provides classroom materials, suggestions for student activities, overviews of projects undertaken in 19 countries, and more, created especially for K-12 students and their teachers.

World Food Programme: Hunger
wfp.org/hunger

Crisp, clean, and easy to navigate, this site presents statistics, frequently asked questions, and a look at the goals of this organization—the world's largest anti-hunger agency. Blog via Friends of the World Food Program at friendsofwfp.typepad.com.

World Bank Millennium Development Goals: Goal 1 Data
tinyurl.com/lkstud

Browse these pages to learn more about the financial and technical assistance—aimed at fighting poverty and hunger—that the Washington, D.C.-based World Bank provides to developing countries.

International Food Policy Research Institute
ifpri.org/data/data_menu.asp

Policy papers, project reports, data sets, and a Global Hunger Index developed by the researchers at this renowned institute are easy to find at their knowledge-rich site. Those interested in policy will want to visit Blog World Hunger at ifpriblog.org.

Household Food Security in the United States, 2008
ers.usda.gov/briefing/foodsecurity

Regarded as the most authoritative federal compilation of statistics on food insecurity in America, this overview from USDA's Economic Research Service shows that at times during 2008, Americans in 15 percent of the nation's households reported not having adequate food. "USDA Study Shows Hunger on the Rise in U.S.," a National Public Radio Talk of the Nation broadcast, provides commentary at tiny.cc/hunger437.

Addressing Global Hunger and Poverty Through Agricultural Development
tiny.cc/SRUI4

Experts in agricultural research and food aid discuss efforts to improve the lives of smallholder farmers in Africa and Asia during this 2-hour webcast, sponsored by the University of California-Berkeley and the Bill & Melinda Gates Foundation.

National Agricultural Library Database of Articles on World Hunger
tinyurl.com/DNAL-WorldHungerArticles

Updated regularly, this substantial database provides citations for nearly 1,700 journal articles on world hunger.

World Hunger Books in the National Agricultural Library
tinyurl.com/DNAL-WorldHungerBooks

Citations for more than 700 noteworthy books on world hunger appear here, with additions made on an ongoing basis.

ARS National Research Programs in Genomics and Genetics for Food Security

The Agricultural Research Service is a leader in developing and using genomic data to improve the development of agriculturally important animals, crops, ornamentals, insects, and microorganisms.

ARS's genomics research program is concentrated in three of the agency's national programs: Food Animal Production (NP #101), Plant Genetic Resources, Genomics, and Genetic Improvement (NP #301), and Plant Biological and Molecular Processes (NP #302). But genomics research has very broad applications, and research projects often involve extensive collaborations with other ARS national programs, such as Food Safety (NP #108), Animal Health (NP #103), Plant Diseases (NP #303), and Bioenergy and Energy Alternatives (NP #307). These and other national programs are described at www.nps.ars.usda.gov.

Sequencing genomes enormously expands our understanding as well as the number of genes that can be deployed to address aspects of better world food security and to increase sustainable food production. But such genome programs are too big and too expensive for any one agency—or even one country—to take on.

ARS continues to play a major role in forming the international committees and coalitions that select which genomes should be tackled next and ensuring that research tasks are complementary, not duplicative.

Because of the huge potential that genomics offers for improving crops, ARS has set a goal of developing genomic libraries with genotypic and phenotypic information for all accessions in the National Plant Germplasm System. This is a massive but accomplishable job.

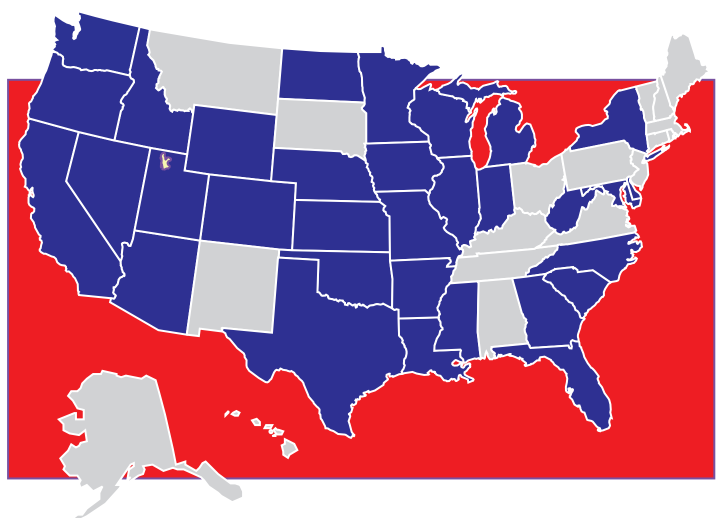
On the livestock and poultry side, ARS is leading a major effort to use genomics to improve the efficiency of animal production, especially in the area of feed utilization, to help reduce costs for producers and consumers, and to reduce the environmental impact of agriculture. Research projects will also be using genome sequence data to develop a better understanding of the host-pathogen relationship for the most dangerous animal pathogens and to enhance our understanding of the immune response to enable improved vaccines and postvaccine technologies.

ARS plant and animal genomics programs are also coordinating the development of new informatics tools for management, collection, storage, retrieval, and analysis of the large data sets being generated by genomics. This coordination includes promoting the integration of "-omics" data with large-scale phenotypic studies and the development of software to incorporate genome-level data into national and international genetic evaluation programs that support standards of interoperability, data validation, and quality assurance; and also promoting accessibility of the published data.

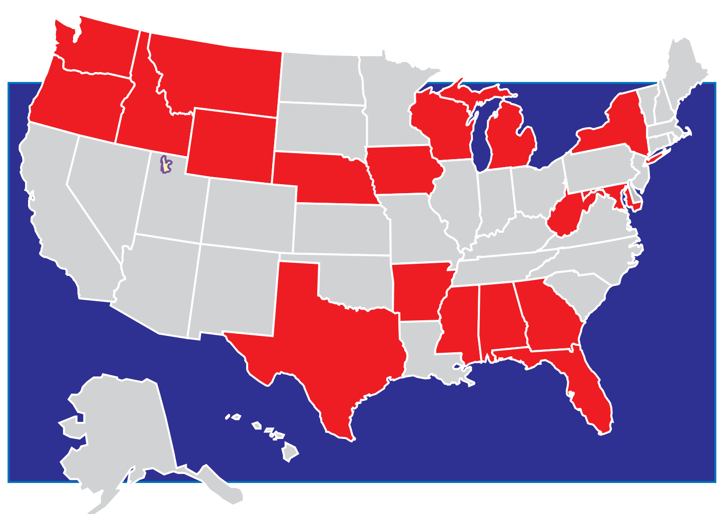
The goal is to maximize accessibility, utility, and use of genomics data; avoid duplication; and leverage developments from other research communities. ARS is also promoting the development and evaluation of technologies for rapid assessment of genomic diversity to guide the choice of candidates for whole-genome sequencing.

Food security is an international issue. The research to put genetics and genomics to work to enhance food security is also an international effort, one in which ARS plays a leading role. ✷

States Where ARS Does Plant Genomics Research



States Where ARS Does Animal Genomics Research



A New Approach to an Old Problem: Devising Formulas To Enhance Growth

PETER D'AIUTO (D1796-1)

Geneticist Randall Niedz (left) and ecologist Terence Evens inspect two green algae cultures for an ongoing study of the effects of fertilizers on algal growth.

Two researchers at the U.S. Horticultural Research Laboratory in Fort Pierce, Florida, are attracting international attention in diverse scientific fields for their approach to a common problem in science: how to predict every possible variable in an experiment where you simultaneously manipulate numerous components.

Researchers who use culture media to grow and study cells, tissues, or any biological entity typically try to optimize the media by varying one ingredient at a time, while holding all the other ingredients constant. The problem is that changing the amount of any single ingredient in a mixture changes not only the amount of that ingredient, but also its proportion to every other ingredient in the mix. The one-ingredient-at-a-time—or one-factor-at-a-time—approach fails to take into account the effects of proportions. In addition, this can be an expensive and time-consuming process, with no significant improvement in culture growth.

But geneticist Randall P. Niedz and ecologist Terence J. Evens have developed a new approach that can help researchers reformulate any type of mixture, whether it is a culture medium, fertilizer, potting soil, insect diet, or animal feed.

Niedz and Evens encountered the problem a few years ago while each was studying mineral nutrients. Niedz was trying to improve the growth of citrus tissue culture, an important area for crop improvement, but one that tends to be a challenge. Evens was studying the effects of algal growth in runoff from ornamental plants in nurseries.

A typical plant/algae culture medium contains about 16 individual mineral nutrient ions, and its effects are determined by both the amount and the proportion of each ingredient in the mix. Niedz and Evens recognized that creating a nutrient solution is a special type of mixture problem and should be defined by the composition of its individual ions. They found that by examining ions independent of their parent salts, they could make sense of the specific ion effects in their solutions.

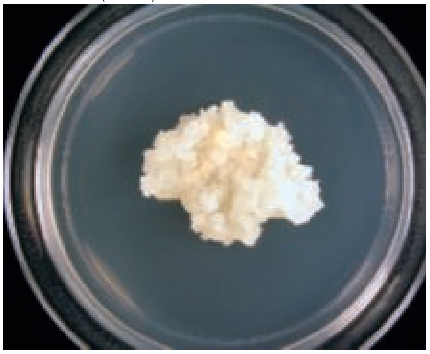
The method they developed of reconfiguring a "recipe" is complex and must be done with a computer using both an algorithm they devised and experimental designs that separate out the effects of proportionality and amount. Results are teased out in ways that reveal every possible outcome and are considerably more accurate, resource efficient, and knowledge rich than results from standard one-ingredient-at-a-time approaches, the researchers say. When applied to citrus tissue and algal culture, the results were dramatic, saving time and money and enhancing cell growth. In the citrus experiments, growth of citrus tissue cultures increased nearly 200 percent. In the algal experiments, they found unusual mixtures where algae grew vigorously and at pH levels far beyond where traditional science said they should grow.

The approach developed by Niedz and Evens is being used not only by scientists in their fields, but also by entomologists, medical researchers, and even chemists around the world to gauge the effects of varying ingredients in mixtures. They explained the approach in a letter to *Nature Methods* in June 2006 and a report in *Scholarly Research Exchange* in May 2008. They have also released a free online software package, for mineral nutrient research, that has been downloaded more than 300 times by scientists in 39 countries. The software package is available at www.ars.usda.gov/services/software/download.htm?softwareid=148.—By **Dennis O'Brien,** ARS.

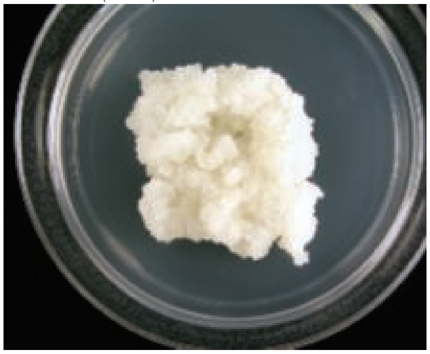
The research is part of Water Availability and Watershed Management, an ARS national program (#211) described at www.nps.ars.usda.gov.

Randall P. Niedz and Terence J. Evens are with the USDA-ARS U.S. Horticultural Research Laboratory, 2001 South Rock Road, Fort Pierce, FL 34945; (772) 462-5919, randall.niedz@ars.usda.gov, (772) 462-5921, terence.evens@ars.usda.gov. ✷

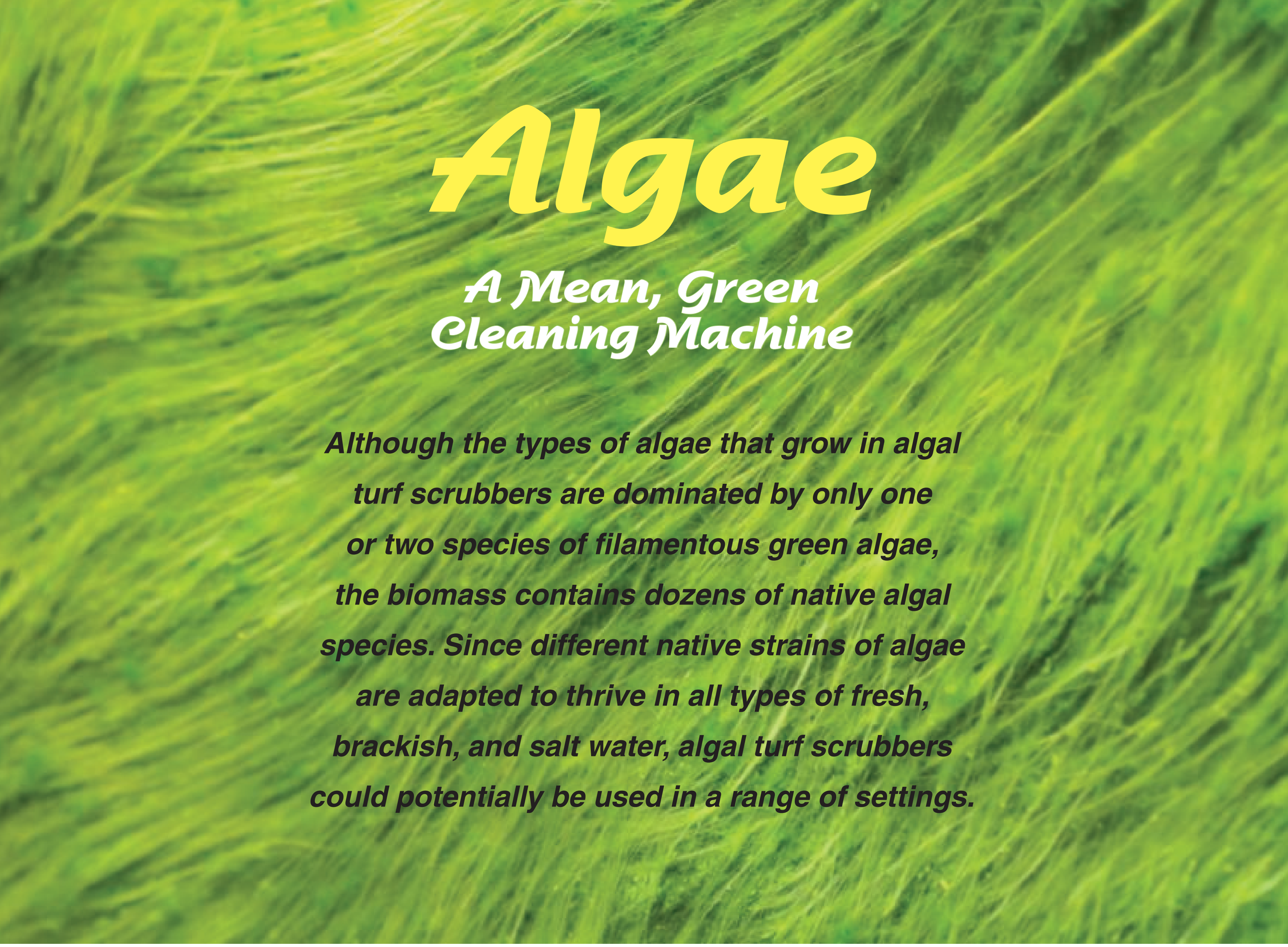
ELDRIDGE WYNN (D1785-1)



ELDRIDGE WYNN (D1786-1)



Citrus cell lines growing on standard media formulation (left) and on a formulation identified after a single experiment using the new ion-based approach. The cells on the new formulation are growing almost 200 percent faster. The new approach can be used to make better formulations for many things, including potting soils, animal diets, fertilizer blends, and algae nutrient solutions.



Algae

A Mean, Green Cleaning Machine

Although the types of algae that grow in algal turf scrubbers are dominated by only one or two species of filamentous green algae, the biomass contains dozens of native algal species. Since different native strains of algae are adapted to thrive in all types of fresh, brackish, and salt water, algal turf scrubbers could potentially be used in a range of settings.

EDWIN REMSBURG (D1756-1)

It sounds like a late-night infomercial pitch: a plant that grows at a monstrous pace in polluted water, soaks up CO_2, and cleans up manure runoff.

Agricultural Research Service microbiologist Walter Mulbry has been finding out there's more to algae than just stringy masses that muck up streams and ponds. Though some scientists believe algae might be the next best thing in biofuel production, Mulbry thinks it can be used right now to reduce the nitrogen and phosphorus in livestock manure—and then dried and sold as a slow-release fertilizer.

Livestock manure is used as a cheap and abundant field-crop fertilizer because it contains large amounts of nitrogen and phosphorus, which are both essential plant nutrients. But some of the nitrogen and phosphorus that isn't used by the crops can be washed into nearby streams and rivers and end up in the Chesapeake Bay.

Like cultivated field crops, aquatic plants grow and flourish when nitrogen and phosphorus are plentiful. When these plants die, their decomposition robs the bay of oxygen, which in turn harms other aquatic life. A 2005 report by the Chesapeake Bay Foundation, whose motto is "Save the Bay," estimated that animal manure contributes 18 percent of the nitrogen and 27 percent of the phosphorus that drain into the Chesapeake Bay every year.

"Other researchers have looked at using algae-based systems to clean up municipal wastewater and other types of polluted water," says Mulbry, who is with the ARS Environmental Management and Byproduct Utilization Research Laboratory in Beltsville, Maryland.

"So we built on that concept and focused on tracking manure nitrogen and phosphorus through the treatment system. Nutrient recovery values—comparison of the amounts of manure nitrogen and phosphorus that are added to the system with the amounts of algal nitrogen and phosphorus removed from the system—are surprisingly difficult to measure in the field because of frequent changes in manure characteristics."

In 2003, Mulbry set up four algal turf scrubber (ATS) raceways outside dairy barns at the ARS Henry A. Wallace Beltsville Agricultural Research Center. The shallow, 100-foot-long raceways were covered with nylon netting on which the algae grew. Then for the next 3 years, from April until December, submerged water pumps at one end of the raceways circulated

EDWIN REMSBURG (D1753-1)

University of Maryland ecologist Pat Kangas (left) and ARS microbiologist Walter Mulbry examine algae growing on a shallow raceway at the BARC Dairy Research Unit. Mulbry estimates that each acre of raceway could remove the nutrients from the manure of about 20 cows.

EDWIN REMSBURG (D1754-1)

Analysis of air-dried algae (shown above) from an algal turf scrubber showed that the algae captured most of the nitrogen and phosphorus in the manure. With additional processing, the dried algae could be sold as a slow-release organic fertilizer or as an animal-feed supplement.

a mix of fresh water and raw or anaerobically digested dairy manure effluent over the algae.

Just Add Water and Stir

Within 2 to 3 weeks after the ATS system was started up each spring, the raceways supported thriving colonies of green filamentous algae, including *Rhizoclonium hieroglyphicum*—the most abundant algae species, and *Microspora willeana, Ulothrix ozonata,* and *Oedogonium* sp. Algae growth was highest in the spring and declined during the summer months in part because of the higher water temperatures and also because the raceways provided snails and midge larvae ample opportunity to graze on the algae.

Working with postdoctoral researcher Elizabeth Kedebe-Westhead and others, Mulbry harvested wet algae every 4-12 days, dried it, and then analyzed it for nitrogen and phosphorus levels. Results indicate that the ATS system recovered 60 to 90 percent of the nitrogen and 70 to 100 percent of the phosphorus from the manure effluents.

"When we use ATS management, we are able to remove the nutrients completely," Mulbry says. But he also notes that, unlike other management practices, ATS systems have high capital costs and require people onsite to harvest the algae. Even so, Mulbry calculated that the cost for this capture was comparable to other manure-management practices—around $5 to $6 for each pound of recovered nitrogen and around $25 for each pound of recovered phosphorus.

The potential benefits don't stop with nutrient capture. Mulbry also studied whether the dried algae had potential as an organic fertilizer. He found that corn and cucumber seedlings grown in algae-amended potting mixes performed as well as those grown with commercial fertilizers.

"It's possible that farmers using ATS management could sell the dried algae as an organic fertilizer for use by urban and suburban residents. It's a ready-made 'Save the Bay' fertilizer," Mulbry says.

The Not-So-Distant Shore

Now Mulbry is partnering with University of Maryland scientist Patrick Kangas and researchers from the State of Maryland and Caroline County on a study under way on Maryland's Eastern Shore. They want to see whether farmers there who use poultry litter for fertilizer can also use ATS systems to clean up nitrogen and phosphorus runoff in field ditches.

Maryland's Eastern Shore—where five counties are among the leaders of broiler production in the United States—has hundreds of miles of managed drainage ditches and in-field connectors crisscrossing thousands of acres of cropland. In 1999, the Public Drainage Task Force in Maryland was charged with developing recommendations for changing public-drainage management, which would help reduce the amount of agricultural pollutants flowing into the Chesapeake Bay.

Mulbry is contributing to the study of different ATS systems to identify the most important factors in designing a cost-effective approach to their use in ditch management. "We're looking at several approaches," he says. "How do we make this as cheap as possible? How does it compare, cost-wise, with other management practices? And what would a business plan look like to the service provider and to the farmer?"

Mulbry also conducted a study to see how effective ATS systems are at removing nitrogen and phosphorus from three estuaries that drain into the Chesapeake Bay. "We started out treating manure on the farm to prevent pollutants from entering the watershed," he says. "Now we're looking at ways to capture pollutants after they've left the farm and are on their way to the bay."—By **Ann Perry,** ARS.

This research is part of Manure and Byproduct Utilization (#206) and Food Safety (#108), two ARS national programs described at www.nps.ars.usda.gov.

Walter Mulbry is in the USDA-ARS Environmental Management and Byproduct Utilization Laboratory, 10300 Baltimore Ave., Bldg. 306, Beltsville, MD 20705; (301) 504-6417, walter.mulbry@ars.usda.gov. ✷

True Origins of Widely Used Potato Germplasm Revealed

STEPHEN AUSMUS (D1759-3)

In a greenhouse at the Vegetable Crops Research Unit in Madison, Wisconsin, botanist David Spooner works to identify the origins (or species) of potato germplasm known as "Neo-Tuberosum."

Thanks to Agricultural Research Service botanist David Spooner and cooperators, potato breeders around the world now know the truth: some of the germplasm they're using to develop new cultivars doesn't come from where they thought it did.

Spooner, who is with the Vegetable Crops Research Unit in Madison, Wisconsin, and Marc Ghislain and other colleagues at the International Potato Center in Lima, Peru, recently discovered that potato germplasm called "Neo-Tuberosum" has origins that can be traced to southern lowland Chile, not the Andes as previously believed.

Native or "landrace" potatoes grow in two areas: lowland Chile and the Andes mountains, from western Venezuela south to northern Argentina. These cultivar groups of potato, *Solanum tuberosum,* differ mainly in day-length adaptation, that is, the number of hours of daylight needed for them to "tuberize," or begin to develop potatoes.

The Andean potato, *S. tuberosum* Andigenum Group, is adapted to short-day conditions widespread in the Andes mountains. On the other hand, the Chilean potato, *S. tuberosum* Chilotanum Group, thrives in the long-day conditions farther south, which makes it preadapted to grow in other long day-length environments like Europe and North America.

The Andean potato contains many desirable traits, such as resistance to viruses X and Y, earlier tuberization, and greater yield. In the 1960s, English potato breeder Norman Simmonds sought to take the Andean potato and adapt it for use in long day-length regions. This new potato germplasm was named "Neo-Tuberosum" and is widely used by potato breeders around the world to develop new potato varieties.

Spooner and his colleagues had originally sought to measure how much the genetic base of modern potato varieties and breeders' lines had broadened with respect to the Andean and Chilean landraces. The team used microsatellite genetic markers—tools used by taxonomists to distinguish closely related species—to genotype 193 potato varieties and breeders' lines and help distinguish Andean varieties from Chilean varieties.

These efforts revealed that all six "pure" Neo-Tuberosum clones of the original populations generated by Simmonds and 33 varieties or breeders' lines with an Andigenum pedigree contain plastid DNA markers typical of Chilotanum germplasm. This finding means Neo-Tuberosum germplasm is not strictly a product of interbreeding among Andean potatoes.

"Scientists who study the evolutionary history of an organism will need to reconsider the evolution of cultivated potato species," says Spooner. "This discovery points to a larger series of questions that may change our knowledge of potato classification and identification."

Some of the germplasm they're using to develop new cultivars doesn't come from where they thought it did.

According to Spooner, breeders can now re-examine the value of the material from the Andean potato and will hopefully use it to develop new varieties with traits both farmers and consumers want.—By **Stephanie Yao,** ARS.

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

David Spooner is with the USDA-ARS Vegetable Crops Research Unit, 1575 Linden Dr., Madison, WI 53706; (608) 890-0309, david.spooner@ars.usda.gov. ✷

A Hedge with an Edge for Erosion Control

One way farmers can preserve soil and protect water quality is by planting grass hedges to trap sediment that would likely otherwise be washed away in runoff from the field.

Researchers conducted a series of studies over 13 years to assess the effectiveness of grass hedges for erosion control in wide-row or ultra-narrow-row conventional tillage or no-till cotton systems. They established single-row continuous swaths of a noninvasive variety of miscanthus grass across the lower ends of 72-foot-long plots with a 5-percent slope. Then they tracked how much sediment was trapped by the vegetation from both the wide-row and ultra-narrow-row conventional tillage and no-till fields.

When mature, the hedges captured about 90 percent of eroded sediment from ultra-narrow-row conventionally tilled fields and only about 50 percent of sediment from no-till fields. Nevertheless, the actual soil loss from the no-till plots—either with or without grass hedges—was much less than that from conventionally tilled plots with or without grass hedges, because no-till production greatly reduces erosion. *Seth Dabney, USDA-ARS National Sedimentation Laboratory, Oxford, MS; (662) 232-2975, seth.dabney@ars.usda.gov.*

First Hard Winter Wheat Varieties for Eastern U.S. Production

The first hard winter wheat varieties bred for production in the eastern United States have been developed by the Agricultural Research Service.

Hard wheat, which is used for baking bread, has been a production challenge for farmers in the eastern United States because the area's humidity increases the incidence of disease in the field, which affects yield and grain quality. But NuEast, a new variety of hard red winter wheat, has good grain yield and moderate resistance to powdery mildew and stem rust, including Ug99 races. It also has good resistance to leaf rust.

Another new wheat variety on deck is a hard white winter wheat called "Appalachian White." This variety was tested for 3 years at six locations and consistently produced good yields and better grain quality than other hard white winter wheats tested. Appalachian White also showed a higher level of resistance to powdery mildew, stripe rust, leaf rust, and Hessian fly than other hard white wheats. *David Marshall, USDA-ARS Plant Science Research Unit, Raleigh, NC; (919) 515-6819, david.marshall@ars.usda.gov.*

JACK DYKINGA (K4297-14)

ARS studies show that the antioxidant content of peanuts and their oil is affected by roasting length.

Roasting Does More Than Enhance Flavor in Peanuts

Researchers have shown that increasing roast color intensity steadily ramps up the antioxidant capacities of peanuts, peanut flour, and peanut skins.

Peanuts were incrementally roasted at 362˚F from zero to 77 minutes and then sampled for water- and oil-soluble antioxidant activity levels. Dark-roasting consistently increased water- and oil-soluble antioxidant capacities for both commercially available peanut flours and blanched peanuts. Peanut skins, currently considered a waste product of industrial peanut processing, had remarkably high antioxidant capacities across all roast conditions. Antioxidant increases upon roasting in blanched seed peanut were attributed to greater concentrations of phenolic compounds and/or "browning" reaction products.

The researchers also found that vitamin E degradation was most rapid in oil obtained from lightly roasted peanuts and that oil from darker roasted peanuts had better vitamin E retention than oil from lightly roasted or even raw peanuts. These findings could be a result of increased concentrations of oil-soluble Maillard reaction products, which seem to protect vitamin E from oxidation. *Jack Davis, USDA-ARS Market Quality and Handling Research Unit, Raleigh, NC; (919) 515-6312, jack.davis@ars.usda.gov.*

New Vaccines May Help Thwart E. coli 0157:H7

Researchers have developed two forms of a vaccine that might help reduce the spread of *Escherichia coli* O157:H7 bacteria in calves.

In preliminary tests, 3-month-old Holstein calves were immunized with either form of the vaccine or a placebo. Six weeks later, the animals were given a dose of *E. coli* O157:H7, and for the next 18 days their manure was tested for evidence of the microbe. Vaccinated calves had reduced or nondetectable levels of *E. coli* in their manure within only a few days after being inoculated.

Preventing *E. coli* O157:H7 from proliferating inside cattle helps limit the transmission of pathogens that cause foodborne illness in humans. It reduces the rate of *E. coli* contamination of meat at packinghouses and reduces shedding of the microbe into the animals' manure. It also lessens the chance that manure-borne *E. coli* will contaminate drinking water or irrigation water, which in turns lowers the risk of contamination of fruits, vegetables, or other crops. *Vijay Sharma and Tom Casey, Food Safety and Enteric Pathogens Research Unit, Ames, IA; (515) 337-7279 [Sharma], (515) 337-7726 [Casey], vijay.sharma@ars.usda.gov, thomas.casey@ars.usda.gov.*

U.S. Department of Agriculture
Agricultural Research Magazine
5601 Sunnyside Ave.
Beltsville, MD 20705-5130

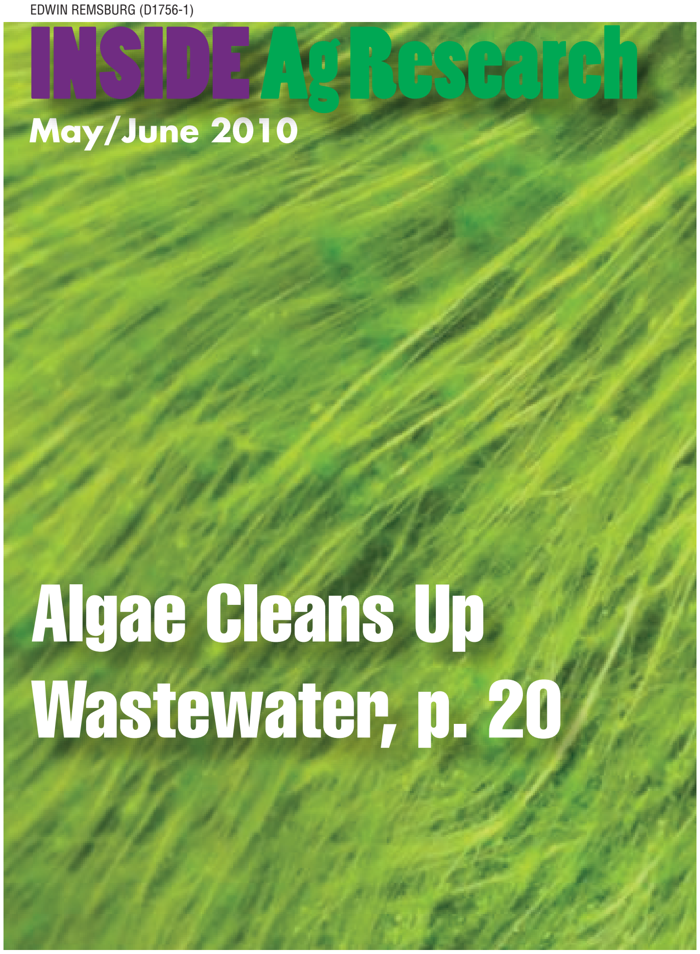
Official Business

PRST STD
Postage and Fees Paid
U.S. Department of Agriculture
Permit No. G-95

Please return the mailing label
from this magazine.

To stop mailing ____ ☐
To change your address ____ ☐

EDWIN REMSBURG (D1756-1)



Visit us on the Web at ars.usda.gov/ar