ARS: 50 Years of Research for the Growing World

In 1953, farmers produced 17.3 bushels of wheat per acre, cows gave 645 gallons of milk per year, U.S. consumers spent 20 percent of their income for food, James Watson and Francis Crick unveiled the structure of DNA, and the U.S. Department of Agriculture formally created the Agricultural Research Service to be its chief in-house science agency.

In the 50 years since then, ARS has been a significant contributor to agricultural progress. Today, in 2003, wheat production per acre has more than doubled to 35.3 bushels per acre, milk production has tripled to 2,160 gallons per cow per year, food costs are down to less than 10 percent of income, and ARS has earned a worldwide reputation as a scientific organization whose research has benefited the farmer, the consumer, and the environment.

The list of the agency's accomplishments is virtually endless: Discovering two new forms of life, constructing the first gene maps of cattle, discovering boron is an essential trace nutrient for humans, testing the prototype laser-beam system for controlling subsurface drainage installation, developing the microinjection technique that moves a whole chromosome into a single cell of another plant, and eliminating screwworms from the United States and other countries are just a few highlights.

But it's not just specific accomplishments that are so important—though many of them have been critical to the continued vitality of U.S. agriculture and to meeting consumers' needs. ARS's work is an essential part of the long research continuum that allows us to become ever-better stewards of our land and water resources, introduce new products based on agricultural commodities, and make our food and agricultural products more affordable, safer, and more abundant.

Food Safety

Safer food at every stage of production—from the farmyard to the processing plant to the dinner plate—is just one area where ARS has made important contributions. For example, for decades, people were taught

SCOTT BAUER (K7222-11)

Lactose-free products from ARS research spare lactose-intolerant consumers an upset stomach and increase dairy sales.

More Food Safety Milestones

In the 1960s, ARS researchers discovered that adding vitamins C and E in the processing could reduce levels of cancer-causing nitrosamines in bacon and nitrite-cured products. As a result, industry changed its processing procedures, minimizing consumer exposure to nitrosamines.

ARS developed methods using calcium to remove strontium-90 radioactivity from wheat and milk in 1962.

One-quarter of all adults cannot digest dairy products. But in 1980, ARS used a bacterium to produce an enzyme that breaks down the milk sugar responsible for the indigestion problem. Today, consumers have access to lactose-free products like milk, cheese, and ice cream as well as Lactaid tablets. Lactose-free milk now constitutes 1 percent of all fluid milk sales, about 40 million gallons a year, and it has boosted milk consumption in the United States by 2 to 3 percent.

STEPHEN AUSMUS (K9988-1)

Cooking ground beef to 160˚F eliminates any danger from pathogenic bacteria such as *E. coli.*

that cooking the pink out of hamburger eliminates any danger from *E. coli* O157:H7 and other pathogenic bacteria. But in 1998, an ARS scientist found color is not a reliable indicator, that only cooking by thermometer, to 160˚F, can assure consumers of the safety of their ground beef.

"The research was originally stimulated by an incident in Seattle back in 1993. Then it took us a while to accumulate enough data to go in the face of what had been believed for so long," says now-retired ARS research food technologist Brad W. Berry. "But we were able to provide accurate and important information about what could be a dangerous problem."

Because of this research, USDA's Food Safety and Inspection Service completely rewrote its hamburger cooking guidelines, consumer outreach materials, and the current regulations based on scientific facts.

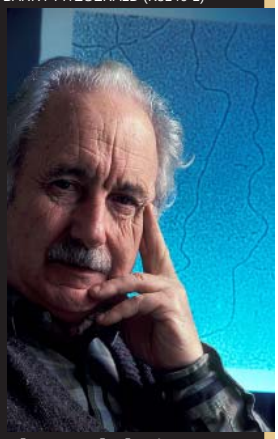
Providing sound science on which regulatory agencies can base their decisionmaking has always been one of ARS's primary missions. For instance, most of the research that proved irradiation is an effective and safe method to sanitize meat came from an ARS laboratory. Today, irradiation is making millions of pounds of ground beef safer from bacterial contamination.

Sometimes, the agency's research in food safety is more basic. An important breakthrough in this area recently came from an ARS-led project that has sequenced the genomes of four *Campylobacter* and four *Listeria* serotypes. *Campylobacter* is believed to cause

Pioneers of ARS

While ARS is first and foremost a problem-solving agency, it has also made some big contributions to basic science. Among them are 2 of the top 10 milestones for the past 100 years of plant pest and pathogen research as selected by the American Phytopathological Society (APS), both for discovering a new form of life.

BARRY FITZGERALD (K3146-1)



Plant pathologist Theodor O. Diener.

Number four on the APS list is the discovery of the viroid. In 1971, ARS plant pathologist Theodor O. Diener uncovered these pathogenic RNA-only molecules, which are 80 times smaller than viruses. A single viroid was found to cause more than a dozen different plant diseases. But when Diener announced his discovery, he was overturning the scientific dogma that held that an organism with no proteins wasn't supposed to be able to replicate itself. And an entity as small as the potato spindle tuber viroid—at only 130,000 daltons—wasn't supposed to be able to infect anything, even a potato.

The seventh most significant, according to the APS list, is the 1972 discovery by ARS plant pathologist Robert E. Davis of spiroplasmas, mycoplasma-like life forms with no cell wall and one of the smallest genomes of any living organism. Spiroplasmas cause many plant diseases.

ARS biochemist Robert Holley took home a share of the 1968 Nobel Prize for Medicine or Physiology for leading a team that isolated and characterized the first nucleotide sequence of transfer ribonucleic acid (tRNA), a basic building block of life.

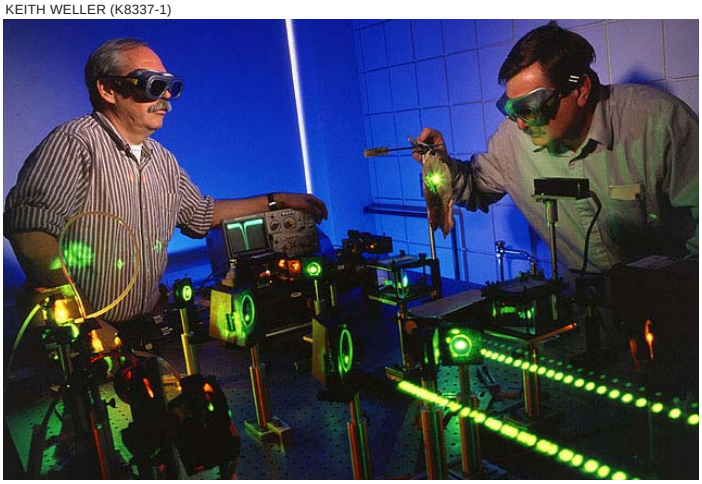
Sterling B. Hendricks led the team that identified and characterized phytochrome in 1957, the physico-chemical agent that regulates all aspects of plant growth from germination to flowering to fruiting in response to changes in amount of daylight.

SCOTT BAUER (K4722-6)

Entomologist Edward F. Knipling.

ARS entomologist Edward F. Knipling invented the sterile male insect release biocontrol technique. Using this technique, screwworms have been eradicated from the United States, Mexico, and other countries. The technique is now also used to control Mediterranean fruit fly outbreaks, the tsetse fly, and other pests. Knipling is also considered the founding father of the areawide integrated pest management concept.

KEITH WELLER (K8337-1)



Research with lasers and reflected light has resulted in new handheld scanners that can detect bacterial contamination on meat carcasses. The scanners may revolutionize meat inspection and increase food safety for consumers.

more than 2 million cases of foodborne illness in people each year, and more than 500 people die of listeriosis annually, according to the Centers for Disease Control and Prevention.

"Armed with this genetic information, we'll be able to identify specific bacteria. This will let researchers and epidemiologists truly trace back specific illness outbreaks and really learn exactly how contamination spreads," explains ARS Food Safety National Program co-leader James A. Lindsay. "This will be essential information for the epidemiologist to find out how and why people are exposed."

Now, taking food safety to the next level is cutting-edge ARS research that just reached the market—a new light-based scanner that can inspect beef carcasses for possible microbiological contamination by measuring changes in reflected light. The Sebastian, Florida-based eMerge Interactive, Inc., is already providing the handheld scanner to companies that account for more than 80 percent of the beef marketed in the United States.

"These sensors are going to have a very significant impact on the safety of food in the next 2 to 3 years," says Dell M. Allen, Vice President of Technical Services for Cargill Meats Solutions of Wichita, Kansas, one of the major companies implementing the new sensors. "It's going to allow the industry to do much more accurate checking than by visual inspection and make sure meat is free of contamination."

Animal Science

ARS's research has also contributed to improvements in every facet of beef production, Allen points out.

"Over the past 20 years, we've seen an increase of probably 50 to 70 pounds per carcass, which is one of the reasons that

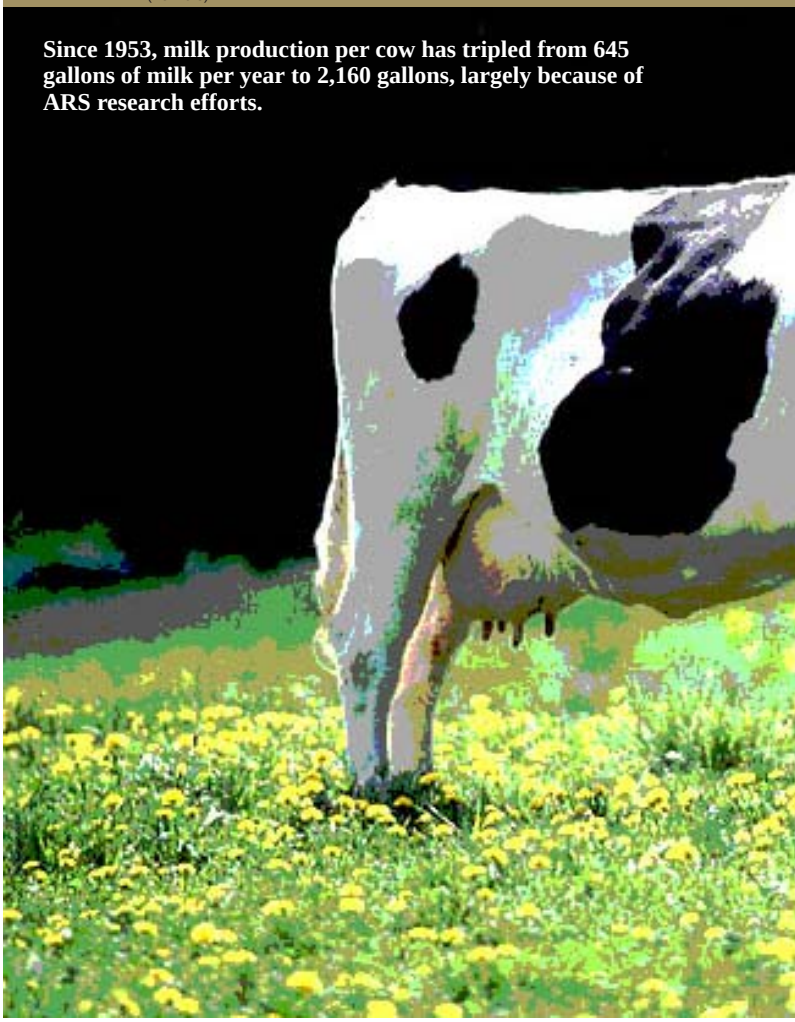
More Animal Research Milestones

In 1967, ARS researchers discovered that a herpes virus caused Marek's disease in poultry. This was the first cancer shown to be caused by a herpes virus. Four years later, an ARS-developed vaccine for Marek's disease became available and saved producers $30 million in losses in the first year. This 1-year's savings equaled nearly 100 percent of the 10-year investment of $32 million it took ARS to develop the vaccine. The National Cancer Institute has cited this vaccine as one of the single most important developments in cancer research.

Other effective animal vaccines ARS has developed include those against avian leukosis and Newcastle disease in poultry; enteric septicemia in catfish, a bacterial disease that causes losses of up to $50 million annually to U.S. catfish farmers; and a foot-and-mouth disease vaccine that was the first effective

KEITH WELLER (K5176-3)

Since 1953, milk production per cow has tripled from 645 gallons of milk per year to 2,160 gallons, largely because of ARS research efforts.



subunit vaccine created through gene splicing for any animal or human disease.

ARS devised a way to separate living sperm into male- and female-producing batches, which may have great significance for the livestock industry. The method has already been put into practice in human medicine.

Procedures developed by ARS are still used around the world to control mastitis, an udder disease that costs U.S. dairy producers $1.7 billion annually. In 2000, ARS created the first cloned transgenic cow with an inserted bacterial gene. This gene allows a cow to produce an enzyme that destroys mastitis-causing bacteria.

A rapid, accurate diagnostic test was developed by ARS in 1963 for hog cholera, which was the most devastating disease of swine in the United States for more than a century. Along with other ARS research, this test helped lead to the complete eradication of hog cholera in the United States by 1978.

SCOTT BAUER (K9269-1)

Advances in ARS labs help make feed for animals and food for people safer. Here, scientists work with a bacteria that may help prevent *Fusarium* fungi from infecting corn used for animal feed.

beef prices for consumers have stayed low," Allen says. "A lot of that weight increase is due to ARS's work over the years, especially in long-term projects like the germplasm evaluation program."

The ARS animal germplasm evaluation project, begun in 1969, has developed an immense amount of reliable information about traits such as tenderness, age at puberty, lean-to-fat ratio, heat tolerance, and reproductive efficiency in a variety of beef cattle breeds.

"This is the kind of long-term sustained effort that an agency like ARS carries out," Allen says. "And a lot of breeders make their decisions today because of the information that ARS has developed. Ultimately, the consumer has benefited by getting better beef."

ARS's genetic research in cattle reached a special milestone in 1994 when the agency created the first genetic linkage map of cattle. Today, ARS makes this data available through the Internet (http://sol.marc.usda.gov), which is helping scientists all over the world continue to improve beef production as specific genes are identified for desirable and undesirable traits.

To help ranch managers deal with diseases like anaplasmosis, which is estimated to be responsible for 50,000 to 100,000 cattle deaths per year, ARS has developed better diagnostic tests. Anaplasmosis is not only a health issue for cattle, it's a trade issue. Cattle that survive the initial infection become lifelong carriers, so those testing positive for anaplasma are restricted from import by other countries, especially Canada. The ARS test is able to identify disease-free areas in the United States, which can reduce trade regulation for U.S. producers. Canada recently adopted the ARS test as its national standard for anaplasmosis diagnosis.

Nutrition

It's not just making food safer or more abundant that concerns ARS; the agency has also been a leader in human nutrition research.

"Without ARS, human nutrition would be a much more fragmented field than it is today. All along, ARS has focused the research toward optimum human nutrition," says Johanna Dwyer, director of the Frances Stern Nutrition Center at the Tufts New England Medical Center, and professor of Medicine, Nutrition and Community Health at Tufts University Medical School and at the Friedman School of Nutrition Science and Policy. "Back 25 to 30 years ago, everybody else was thinking of nutrition only as if it were just an antidote to disease instead of focusing on what the body actually needs and why."

ARS has been a pioneer in learning how human nutrition needs vary by age, gender, race, body type, and other factors. For example, ARS researchers found a link between cataract development and lower levels of vitamin B6, folate, and taurine in the diets of the elderly. They also showed a relationship between vitamin C intake and blood pressure in the elderly. And ARS research found a relationship between dietary calcium and manganese and women's menstrual cycles.

Research such as this by ARS and others has given rise to the new, more detailed nutrition guidelines called Dietary Reference Intakes (DRIs) established in 2001, which updated the Recommended Dietary Allowances first created in 1941. ARS played a lead role providing a great deal of the detailed, reliable data used in setting appropriate DRIs for a variety of groups of people.

For example, ARS studies of vitamin K showed the longstanding recommended levels of this vitamin may have been too low for optimal bone health. What's more, ARS data was used to help develop recommendations for a new category of DRI's known as Tolerable Upper Intake Levels. These are the highest amounts of a nutrient that can be safely consumed on a daily basis.

ARS is also home of the national food consumption surveys that find out what people are actually eating. This data continues to be invaluable when it comes to learning about the nutrition-related behavior of the U.S. population. Data from the ARS Supplemental Children's Nutritional Survey in 1999 were the basis for EPA's new regulations that ensure the food we eat does not contain harmful levels of pesticide residues.

PEGGY GREB (K9315-1)

From the farm to the table, ARS research is helping to better understand human nutrition on many levels, from determining what nutrients are in food to what the body needs in the optimum diet.

A third mission of ARS's longstanding human nutrition research program is maintaining the USDA National Nutrient Database for Standard Reference, which lists more than 40 components from fat and protein to individual vitamins and minerals for 6,661 foods. Optimum diets cannot be formulated unless you know what nutrients are in the foods we eat.

"Establishing food composition data is the kind of long-term, sometimes low visibility research that may not have much pizzazz but is essential to human nutrition," Dwyer says. "The research may not be high profile, but we must have this information."

New priorities for ARS research constantly arise in answer to new problems. In the past few years, obesity has become a more important research focus for ARS, as the problem has become epidemic in the United States. The agency is working on projects as diverse as discovering hormonal and metabolic changes that result in overeating to studies on how to influence kids' behavior so they will want to be more active and to eat nutritious foods.

People's diets have also benefited from healthy ingredients developed by ARS. On a wide variety of food ingredient lists appear some form of the words "hydrolyzed oat flour or oat bran." A lot of that is actually ARS's patented Oatrim, a replacement for shortening—made from enzyme-treated oats and barley—that can reduce total calories and cholesterol in food products. Oatrim has been licensed to several companies, including Quaker Oats, Inc., which uses it in foods like some Healthy Choice dinners. Oatrim production was estimated to be in excess of 20 million pounds in 1999, resulting in more than $1 billion in retail sales.

Deep Roots

While ARS celebrates its official 50th anniversary this year, the agency has deep roots. When Abraham Lincoln created the U.S. Department of Agriculture in 1862, the legislation called for the new entity to acquire "useful information connected with agriculture in the most general and comprehensive sense."

Bureaus and programs were created within USDA over the years to conduct all types of scientific research in agriculture. Many of these were merged in 1953 to form the nucleus of the Agricultural Research Service. This depth of background has always been an important part of ARS's ability to contribute to agricultural advances. Agricultural research, like all science, is a continuum, a spiral that builds on its past. Since

SCOTT BAUER (K4610-12)

The human nutrition research program is helping discover how people's nutritional needs differ by gender, age, activity level, and many other factors such as the impact of weight training on bones and calcium.

Research Milestones from ARS's Roots

Alexander Fleming discovered penicillin in 1928, but not until 1941 was penicillin mass producible. At a Peoria lab that became part of ARS in 1953, scientists developed the deep fermentation technique that was the breakthrough leading to mass production, just in time to save thousands of lives in World War II. The deep fermentation method ARS developed for penicillin production and outgrowths from this technology have since been instrumental in development of many other important antibiotics.

Scientists from what would become ARS labs collaborated with Florida Citrus Commission researchers in 1948 to perfect a method to produce practical, flavorful frozen orange juice concentrate with all its vitamins and minerals. Today, consumption of orange juice from frozen concentrate—still made using these methods—comes to over 1.07 billion gallons a year in the United States.

The herbicide 2,4-D was developed in 1942 at the Beltsville [Maryland] Agricultural Research Center, now ARS's largest location. It remains one of the most effective and safest broadleaf herbicides available.

SCOTT BAUER (K7237-8)

(K10839-1)

USDA plant explorer Frank N. Meyer, pictured here following a plant collection trip in the mountains of China in 1908, was an early luminary who brought back plants from apples to zoysia grass.

its creation, ARS has provided continuity for all USDA research.

For example, ARS's nutrition research is a direct descendant of the work of Wilbur O. Atwater, USDA's first chief of nutrition investigation, who is widely regarded as the father of modern nutrition research and education. Just over 100 years ago, Atwater made the first modern food composition analysis in the United States. His work was the beginning of the program which ARS maintains today as the USDA National Nutrient Database for Standard Reference.

Another example of how ARS carries on the historic work of USDA is the dairy herd improvement program, started by USDA in 1910 and still run by ARS today. The program began keeping detailed records of milk output and other characteristics used to decide breeding choices. During the first 10 years, this led to an average yearly milk production per cow increase from 5,354 to 6,637 pounds. Today, total milk production of cows has increased more than four-fold from this program, specifically tripling in the last 50 years.

Crops and Plants

One of USDA's oldest ongoing programs—plant germplasm exploration, preservation, and distribution—is continued today in ARS as the National Plant Germplasm System (NPGS).

Plant exploration and collection from all over the world are essential for agriculture because crops must be continually enhanced to overcome diseases and pests, expand drought and temperature tolerance, adapt plants to new growing conditions, and make them more productive, nutritious, and durable—or simply better tasting. Also, agricultural plant biodiversity is eroding as growth in global human population forces shifts in land uses and more displacement of indigenous crops.

KEITH WELLER (K7743-13)

Exotic items like these unusual maize specimens from Latin America are preserved in the ARS National Plant Germplasm System because they might have genes to help solve future problems.

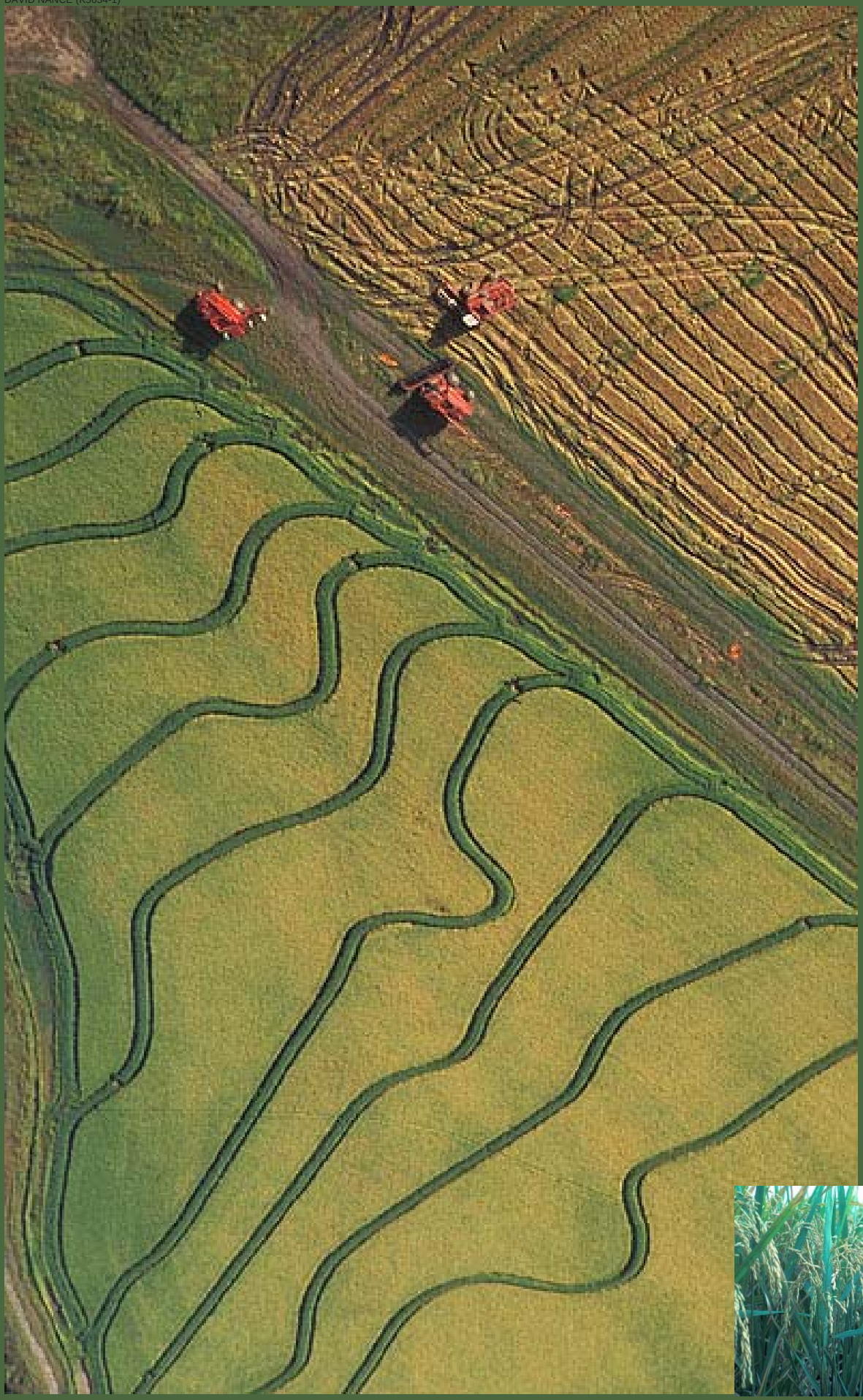
Roots of ARS's current germplasm collecting go back to the likes of USDA plant collector Frank Meyer, who has had a remarkable impact on U.S. agriculture. From 1905 to 1918, he brought back samples of plants from apples to zoysia grass. One of Meyer's most significant contributions was soybeans. Before he went to China in 1905, only eight varieties of soybeans were grown in the United States, mostly for animal forage. By 1908, Meyer had added 42 new soybeans, which have parented thousands of varieties over the years. Among the soybeans he collected was the one that gave rise to U.S. soybean oil production, an industry worth billions of dollars today.

Tracking the effect of what Meyer and other USDA explorers have brought back over the years is hard, because decades can pass before collected plants may be bred into a new variety. For example, the zoysia grass that Meyer collected in the early years of the century did not evolve into a commercial variety until 1951.

Today, NPGS is ARS's responsibility and a vital world resource. It consists of the National Center for Genetic Resources Preservation (NCGRP), in Fort Collins, Colorado, two dozen ARS-operated repositories located across the country, and the Germplasm Resources Information Network (GRIN), the database system that collects and makes available information on genetic resources. This ARS-developed system has enabled sharing of germplasm information around the world.

"Before the advent of the NPGS, collections basically belonged to individual researchers and depended on whether and how they kept records and on what they had collected,"

DAVID NANCE (K5634-1)



Improved plant varieties like the rice being harvested in this field are a regular result of ARS research. More than half the rice grown in the United States comes from ARS-developed varieties. The high quality of this rice helps explain why 1 of every 5 bushels on the world market is grown by U.S. farmers.

In 1993, this ARS-developed rice variety, called Lemont, covered 600,000 acres in Arkansas, Louisiana, Mississippi, and Texas.

DAVID NANCE (K2958-2)

explains NCGRP director Henry Shands. “Things were managed for the individual research programs, which wasn’t a problem for the success of those research programs. But it didn’t leave information and plants especially accessible for others to use.”

In addition to the data in GRIN, ARS sends out more than 100,000 germplasm samples each year to researchers in many countries. The program also trains foreign scientists and technicians in germplasm preservation as part of its exchanges with other countries and even acts as a backup storage depot for germplasm collections of countries that fear catastrophic losses.

Filling the Cornucopia

Of course, ARS itself has also put germplasm to work, producing crop varieties that have served critical needs for agriculture.

SCOTT BAUER (K7229-28)

Almost all of the blueberries and cranberries in commercial production were either developed by ARS or bred from ARS varieties.

Take B73 corn, a result of a joint ARS and Iowa State University research program in the 1970s and 1980s. B73 remains the basis for virtually all the seed-parent lines of corn throughout the United States and much of the rest of the world. In 1990, it was found that the lines from this program were so widely used that they had made their way into most commercial corn produced in the U.S. Cornbelt. These lines produce an estimated $1 billion per year for the American farmer. In part because of such improved breeding lines, average U.S. corn yields in the past 40 years have more than doubled.

So widespread are ARS’s plant improvements, that consumers are very likely to be buying a product of ARS research any time they shop for produce. New flavors, extended harvest seasons, increased growing range, and better shelf life are just a few of the improvements ARS researchers have made.

Almost all blueberries and cranberries in commercial production were either developed by ARS or bred from ARS varieties. ARS also brought consumers supersweet strawberry varieties with longer shelf life. Southern-grown fresh peaches would probably not be readily available to consumers in eastern U.S. markets if ARS had not developed improved peach varieties as well as the Guardian rootstock.

More ARS Crop Improvements

More than half the rice grown in the United States comes from USDA-developed varieties. The high quality of this rice is one of the reasons that 1 of every 5 bushels of rice on the world market is grown by U.S. farmers. USDA has also developed rice-growing practices that use fewer herbicides and other chemicals.

The Roma tomato was released by ARS in 1955, and it is still the main variety used for tomato paste.

ARS released the Atlantic potato in 1976. It’s still the most popular chipping potato.

Since ARS developed the soybean computer model and decisionmaking software GLYCIM, it has given soybean growers an increase in yield of up to 29 percent and boosted irrigation efficiency up to 400 percent.

A system of crop cultural and control methods put together by ARS has helped lead to the near eradication of the boll weevil, a bug that once wiped out cotton growing in many southern states.

ARS developed a test kit that detects 55 different potyviruses of vegetables and flowers. The test kit is now sold in more than 90 countries and is considered the industry standard around the world.

(K839-7)

A flake of Super Slurper absorbs nearly 2,000 times its own weight in moisture.

Citrus—fresh and processed—also has ARS's imprint all over it. More than 80 percent of the citrus grown in the United States comes from rootstock or fruit varieties developed by ARS. When you buy a sweet red grapefruit, chances are pretty good that it will be a Flame grapefruit from ARS. Most of the early-season tangerines—about a $100 million annual retail product—are ARS varieties Sunburst and Fallglo.

It's not just through better varieties and improved growing techniques, however, that ARS has served farmers. ARS research has also been critical to opening and preserving export markets for U.S. commodities.

When ethylene dibromide, a fumigant used to control fruit flies, was banned in 1984, the U.S. citrus export market became endangered. But ARS scientists developed a new method of controlling fruit flies using cold temperatures to kill the flies without harming fruit. As a result, the $114 million grapefruit export market to Japan was preserved. U.S. exports to Japan of all fresh citrus now total more than $256 million annually.

KEITH WELLER (K8721-3)

Programs like MSEA, which began in 1990, have helped develop and test farming methods that preserve water quality. Here, an ARS scientist collects one of many water samples for a MSEA study.

For the Consumer

ARS not only serves the farmer and rancher; the agency's research has also given rise to many new products to benefit the consumer. Such new products create new markets for agricultural commodities, lead to new jobs in the rural economy, and expand choices for the consumer.

In 1954, ARS developed N,N-diethyl-meta-toluamide, best known simply as DEET, for the Department of Defense to protect soldiers from disease-carrying insects. It's still the most effective mosquito repellant marketed and is even more important now that West Nile virus is in the United States.

Wash-and-wear cotton clothes hit the consumer market in 1958. ARS scientists have played key roles in the research to develop durable press treatments that give cotton and cotton blends wrinkle resistance. Durable press has contributed greatly to the continued popularity of cotton and cotton-blend fabrics.

Today's tasty, convenient frozen foods result largely from pioneering research conducted in the 1940s through the mid-1960s by ARS chemists, engineers, and other specialists. The 17-year project—what became known as the Time-Temperature Tolerance Studies—has been honored as a National Historic Chemical Landmark by the American Chemical Society.

In 1976, ARS scientists invented Super Slurper, a cornstarch derivative capable of absorbing 1,600 times its weight in moisture. Superslurper has been put to dozens of uses—from diapers and baby powder to fuel filters and batteries.

Cold-hardy biodiesel fuel, poinsettias that bloom all holiday season long, detergents that soap well in hard water, instant mashed potato flakes, processed meats 20 to 25 percent lower in salt, and neem-tree-based pesticides popular with home gardeners are just a few more products that have come to consumers thanks to ARS research.

For more on consumer products resulting from ARS research, see *Science in Your Shopping Cart* (www.ars.usda.gov /is/np/shopcartintro.html) and *Agricultural Research*, December 2002, page 4.

SCOTT BAUER (K7225-2)

ARS established the standards that made frozen foods available.

Out of the Lab—Leading in Federal Technology Transfer

Research that stays in the laboratory doesn't end up benefiting farmers and consumers. Getting the work into the marketplace is important. With more than 200 active licenses with companies for patents on research developments and more than 1,000 Cooperative Research and Development Agreements (CRADAs), ARS is a leader in federal technology transfer. In just 2002, a typical year, ARS had 151 invention disclosures, filed 90 patent applications, and was issued 53 patents.

The first federal CRADA signed was between ARS and Embrex, Inc., a biotechnology company started by entrepreneur Harold V. Smith specifically to commercialize a piece of ARS research.

Smith was taking a shortcut across the North Carolina State University campus one hot summer day in 1985 by walking through the poultry science building, when a bulletin board of newspaper clippings caught his attention. The stories were about poultry overtaking red meat as the number one source of protein.

"Those clippings made me stop and think about how the poultry industry had gotten so large, but I knew it also remained a high-volume, high-labor industry," Smith says. "It occurred to me there was a real market for technology that could reduce any of the hand labor.

This intersected perfectly with a scientific discovery made by an ARS veterinary medical officer who found that chicks could be vaccinated through the eggshell for better disease resistance. Traditionally, all chicks had been vaccinated by hand—a method with huge labor costs that often missed some chicks, leading to disease problems.

Smith signed a license agreement with ARS for the in-ova vaccination patent and started Embrex to commercialize the science by automating the in-ova system vaccination technique.

Today, Embrex's automated vaccination machines immunize $120 billion worth of chickens, turkeys, and ducks in 30 countries against diseases like coccidiosis, fowl pox, Marek's disease, and Newcastle disease each year without the work and stress of handling the individual chicks.

The technology has also gone beyond the original idea to give rise to important spinoffs. For example, in-ova technology is now being applied to producing flu vaccine for humans and may provide a way to sort eggs by gender, something very important to the egglaying industry, according to company president Randall L. Marcuson.

"So widely accepted by the poultry industry is in-ova vaccination technology that I don't think you can even put numbers on how much it saves them in labor and preventing loss from disease," Marcuson says. "But ARS discovering the original, core technology—the through-the-eggshell vaccination—at a time when conventional science said it wasn't possible; well, it has really gone on to open a large window of opportunity."

Natural Resources

For ARS, it has never been enough to simply improve agricultural production. The agency is as concerned about preserving natural resources, not only to sustain agriculture into the future, but also to protect the quality of our environment.

The Universal Soil Loss Equation (USLE) and its later revisions are a perfect example. ARS first developed USLE in the 1950s to predict how natural forces and farmers' practices affect soil erosion. Since then, agency researchers have revised and updated USLE as data, understanding, and even computing power have improved.

"It was the first natural resources model to integrate so many factors. Others had little pieces, but this was the first to put together so many factors and take into account how they interacted. It was a real watershed moment for natural resources," explains Mathias J. M. Romkens, director of the ARS National Sedimentation Laboratory.

The soil loss equation remains the prototype for all systems that attempt to model natural processes.

Today, agencies such as USDA's Natural Resources Conservation Service (NRCS) as well as farmers around the world use USLE and its descendants. ARS soil erosion models have led to conservation practices that have reduced erosion by billions of tons of soil in the United States alone.

When it comes to agriculture and water quality, few programs have been as ambitious and successful as the large area studies begun in 1990, when ARS took the lead in a USDA water quality program across the Midwest called Management System Evaluation Areas (MSEA).

The MSEA program was designed to develop and test farming methods that work with nature to protect water quality. The cornerstone of the program has been the close integration of research, extension, and education. It has resulted in farmers being more efficient with nitrogen fertilizer and herbicide applications.

"The practices that provided the greatest benefit to improve surface- and groundwater quality were the implementation of conservation tillage, postemergent applications of nutrients and herbicides, controlled drainage managment systems, and improved irrigation management practices," says Jerry Hatfield, director of the ARS National Soil Tilth Laboratory.

Work like USLE and MSEA highlights another hallmark of ARS—the ability to plan and carry out long-term research. "It's the accumulation of knowledge that lets us make real progress, more so than any single piece of research," says Hatfield. "ARS has always been a leader when it comes to being able to refine and make our practices more sophisticated."

More Natural Resources Milestones

New irrigation inventions from ARS such as surge valves, water measurement devices, and automated controls for both individual field irrigation and water district canals are helping farmers make better use of water resources. Even more water efficiency is resulting from ARS research that has developed a deeper, more accurate understanding of when plants reach stress points and physiologically need water. Water measurement devices, automatic controls, and programs that trigger irrigation based on such physiological needs are making irrigation more precise.

Because of ARS research, western farmers have stopped millions of tons of topsoil from washing out of irrigation furrows by adding small amounts of a safe, erosion-fighting powder called polyacrylamide, PAM for short, to irrigation water.

ARS scientists, working with NRCS and universities, have done the research that has encouraged farmers to largely put away the moldboard plow and switch to conservation tillage on about 40 percent of U.S. planted acres. Adoption of conservation tillage has also improved water use and may have shifted soil from net CO_2 producers to net accumulators of carbon in the form of valuable organic matter.

Impartial Science

Another important role for ARS is that of being the objective voice in potentially controversial issues. A recent case in point: When a letter in the scientific journal *Nature* in 1999 hinted that *Bt* corn pollen (pollen produced from corn plants in which genes from *Bacillus thuringiensis* bacteria were inserted for insect resistance) endangered monarch butterfly caterpillars, it was ARS that led a consortium of industry, universities, and environmental organizations to develop a scientific basis for assessing the actual risk.

"It was not that ARS scientists do better science, although they do great work, but their research is less vulnerable to charges of bias because they're a national resource," says Val Giddings, vice president for food and agriculture for the Biotechnology Industry Organization.

"In the case of *Bt* corn and monarch butterflies, ARS's voice advocating basing any decisions on science meant that industry was able to avoid a rush to an uncalled-for-decision because of media frenzy, and the activists were willing to wait for the science since they believed it would be objective," Giddings adds.

The consortium was able to show that *Bt* corn pollen is a negligible risk to monarch caterpillars, and the U.S. Environmental Protection Agency allowed the re-registration of *Bt* corn varieties in 2001. (Read more about this at www.ars.usda.gov/sites/monarch.)

Today, at 50 years old, ARS incorporates more than 100 locations around the country conducting research in all facets of agriculture, guided by 22 national programs. At any one time, there are more than 1,000 research projects going on in ARS. But more importantly, ARS has a critical mass of scientists at the nation's call.

Teams of experts can be assigned to deal with a potential crisis immediately, before it devastates U.S. agriculture. Such was the case with Karnal bunt. When what looked like an outbreak of Karnal bunt disease threatened the U.S. wheat export market in 1996, ARS quickly developed a test to distinguish between it and a comparatively harmless lookalike fungus. Federal plant quarantine officials now use the ARS technique as a first cut to decide whether quarantine actions are needed. The U.S. wheat export market has an average value of about $5 billion a year.

It is work like this that has made ARS known as the problem-solving agency and why federal funding of agricultural research returns $1.35 for every $1 spent.—By **J. Kim Kaplan,** ARS.

For more information about milestones in this article, contact Kim Kaplan, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; phone (301) 504-1637, fax (301) 504-1648, e-mail kaplan@ars.usda.gov. ★

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In 1999, ARS led a consortium of industry, university, and environmental organizations in assessing the risk of *Bt* corn pollen to monarch butterfly caterpillars. The pollen was found to be of neligible risk to the caterpillars. Here, a large monarch caterpillar feeds on a common milkweed plant.